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The SCIENCE COUNSELOR

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Volume V. SEPTEMBER, 1939 No. 3

CONTENTS

INITIUM FINISQUE 61
Francis Barry

TO HELP YOU TEACH..... 62

THE EXPERIMENT IN SCIENCE TEACHING..... 63
Leon Hervey—Fred M. Schellhammer

THE TROUBLES OF FATHER TIME..... 64
Rev. Charles E. Deppermann

COSMIC RAYS (1900-1938)..... 68
Dorothy Sugrue

DEEP FOCUS EARTHQUAKES..... 70
William A. Lynch

SCIENCE LESSONS AND LIFE PROBLEMS..... 73
Sister M. Geraldine Madden

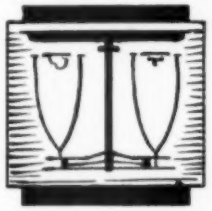
HOW FERNS GROW..... 75
W. N. Steil

A CONDUCTIVITY KIT FOR FIFTY CENTS..... 79
Walter S. Lapp

ON CLASSICAL TRAINING FOR A CAREER IN SCIENCE..... 80
William T. McNiff

Initium Finisque

• **By Francis Barry, 1941**
COLLEGE OF ARTS and SCIENCES
DUQUESNE UNIVERSITY



The last outposts of the myriad, million stars
Are but a prelude to a prelude, the hush before a song.
Dissolve the moon in acid,
Liquefy the sun,
Specify the bird, and flower, and beast—
Better you scatter the palms at the foot of the thunder,
Cover your face from the lash of the hail—
Never will lens of yours find the beginning or find the end,
Never will find the Past—Present—Future.
The sun casts ever its shadow in circles,
The water falls to a bottomless pit,
And the tick of a clock mocks the silent room.
He is the Sea. He comes and goes forever.
The sands shift, but the Sea will have no rest.

To Help You Teach . . .

TWO AIDS FOR TEACHERS OF SCIENCE

ESSAY CONTEST

Duquesne University's national science essay contest, conducted in connection with its annual Conference for teachers of science in Catholic high schools, continues each year to grow in interest and importance. The first contest, held in 1937, attracted a comparatively small number of entries. The contest of 1939 drew scores of essays representing high schools all over the country.

Evidently teachers are beginning to appreciate the value of this contest in stimulating student interest in science. In many cases the essay entered in the national contest has been chosen as a result of a preliminary contest among the pupils of an individual school. This is a practice which should be encouraged. Probably it has some bearing on the fact that the quality of the essays submitted has become notably better, so much so that the judges now find it very difficult to choose the single winning essay. Their decisions are seldom unanimous.

Announcement is now made of the 1940 contest. It is hoped that hundreds of schools will compete. Teachers are not to expect individual invitations for their schools. *This is an official invitation to all Catholic high schools to enter this contest.* It is an invitation to *your* school. No further announcement of the contest will be made.

The essays submitted in this competition will be judged by members of the faculty of Duquesne University. Form, content, and expression will be considered. A gold medal, for permanent possession, will be awarded to the writer of the best essay. Three or more honorable mentions will be made, depending upon the excellence of the essays submitted. A suitably engraved silver cup will be given to the winning school. The cup will be held for one year. It will then be passed on to the school receiving the new award. This cup is now in the possession of Catholic High School, Altoona, Pa., the school which won the 1939 contest.

Announcement of the winner will be made at the next annual Conference for teachers of science which will be held at Duquesne University late in February, 1940. The prize essay will be published in full in the SCIENCE COUNSELOR. Only winning essays and schools will be announced. A list of the schools which enter the contest will not be published.

Schools which expect to submit essays in the contest should so inform the Director of the Science Conference, Duquesne University, Pittsburgh, Pa., by letter or postcard, on or before January 1, 1940. No obligation is incurred by sending such notice.

The rules which are to govern the contest are here given.

RULES FOR ESSAY CONTEST

Subject of the Essay: *Chemical Gardening.* No other subject may be used.

1. Any student enrolled in a Catholic high school, junior high school, or preparatory school, who has not yet completed four years of high school work, is eligible to enter this contest. It is not required that the student shall be enrolled at present in any science course. Catholic students attending public high schools may not compete.
2. Each school may submit *only one* essay.
3. Essays should be typewritten, double-spaced, with good margins, on one side of the sheet only. Legible hand-written manuscripts may be accepted. Essays are to be in essay form. They may not exceed 1,200 words in length. Longer essays will be rejected without reading. All direct quotations must be inclosed in quotation marks and references given. Long quotations are not acceptable. Essays may not be illustrated nor accompanied by charts or exhibits.
4. Each essay shall be the individual work of the student. In its final form it may receive only such supervision as is given in the usual written examinations of the school.
5. A plain, sealed envelope, firmly attached to the essay, must contain the full name, age, and home address of the contestant, the actual number of words in the essay, the name and address of the school, and the name and title of the supervising teacher. No further identification of the writer or the school may appear on the essay or the envelope.
6. Essays must be forwarded by the principal or the supervising teacher with the statement that the essay was written under supervision and that it is the original work of the student.
7. Essays for this contest must be mailed to the Director of the Science Conference, Duquesne University, Pittsburgh, Pa., not later than *February 1, 1940.* Essays will not be returned.

SCIENCE PROJECTS

February, 1940, is not far off.

Today is not too early for teachers of science to begin planning the special student science projects they expect to exhibit at Duquesne University's 1940 Conference. One teacher wrote recently that his material is already complete.

The display of projects is one of the most interesting and helpful features of the Conference. Here teachers learn from each other. Wideawake instructors are always glad to learn of teaching devices or methods that other teachers have found workable and useful. An exchange of ideas may be productive of much good. Duquesne University, therefore, invites teachers every-

Continued on Page Eighty-eight

The EXPERIMENT in Science Teaching

• **By Fred M. Schellhammer, Ph. D.** *(Fordham University)*
and Leon Hervey, M. A., J. D. *(New York University)*
BOTH OF THE BIOLOGY DEPARTMENT, EVANDER CHILDS HIGH SCHOOL, NEW YORK CITY

Is learning by experimentation so all important to the high school student as some educators believe? Are facts to be worshiped blindly? Is the tendency to discourage reference to authority a desirable one? Are there satisfactory substitutes for experimentation? Do our present methods of science teaching really equip pupils to face and solve the problems and difficulties they must eventually meet?

These are but a few of the interesting questions raised here by two experienced teachers.

This out-of-the-ordinary article will challenge your thought.

●

When Bacon and Locke first led science out of the shadow of the Middle Ages by displacing authoritarianism with the scientific method, they brought about a radical change in teaching methods. Today, learning by experimentation is considered essential in science teaching. There are some, however, who go to the extreme of regarding this phase of teaching technique as all important. There is a growing tendency to discourage reference to authority. Knowledge, it is claimed, results from curiosity satisfied by investigation along experimental lines. Unverified information cannot, properly, be classed as knowledge. It is the function of the teacher to develop or create this curiosity, to aid the student to discover facts by marshalling, testing, and checking data.

Few would find objection to methods of teaching which would result in a true understanding of the meaning and application of the scientific method by students. When, however, these methods lead to a disrespect for authority, when they lead to a blind worship of facts, as such, to an insistence on the application of experiment in the judgment of every concept of life and living where experimentation is possible, they fail to equip students to face and solve such problems or situations as they must eventually meet. They lose their effect and values and tend to produce results harmful to a degree.

The average present-day science teacher claims that one of his major aims is to lead his students to understand the difference between theory and fact, between what *may be* and what *is*. The best way to reach this understanding is by discovery, resulting from individual effort. Students must learn by doing. They must experiment, and keep on experimenting. Where difficulties of technique, lack of apparatus, or the time element interferes with such activity, the teacher may use the demonstration method.

Life must be viewed with a question mark. Nothing is a fact unless it is proven such. It is wrong, for example, for the student to experiment for the purpose of finding out "whether saliva digests starch". How does he know what the effect of saliva on a cracker containing starch will be? He must experiment "to find the effect of saliva on starch". There doesn't seem to be much difference. But there is. If he uses the former wording, he presupposes a result. That, he is told, is wrong. Yet, previous to the experiment he has read and been told much to the effect that saliva digests starch. The experiment is evidently for the purpose of corroboration. Yet the wording of the problem may not recognize this fact. He must have an open mind, he is told. He must question the text. He must question the teacher. He must question himself.

So he performs the experiment, expecting a definite result. He may achieve it, but he learns little more than he knew before. The term goes on, and as it does, so does he, learning by experiment and demonstration, for little may be taken for granted. He is expected to repeat experiments, many of which were repeated by his teacher, when a student. Science, he must realize, is ever new, ever old. Though some teachers favor the demonstration method, and others insist on emphasizing student activity, they all apparently agree that students must be given proof of the factuality of practically every scientific conclusion. There can be no effective substitute for experimentation. Students must learn to apply the scientific method. The major transfer values of science accrue from this acquisition.

This last statement has the ring of truth. Yet, there is some question whether teachers who insist that an understanding of the scientific method can be achieved only by observation and experimentation are correct. There is a definite place for the experiment in the science course. Experiments or demonstrations should be conducted when their results illustrate properties of matter that range beyond the experience of the students. When carefully selected, experiments of this type provide interest and inspiration, in addition to instruction in the scientific method.

The greatest value of the experiment occurs not when it merely increases the knowledge of the individual conducting it, but when it actually introduces new information to the world of science. Here is where the scientific method gains its most important results.

Continued on Page Eighty-eight

The Troubles of *Father Time*

• **By Reverend Charles E. Deppermann. S. J., Ph. D.** *(Johns Hopkins)*
ASSISTANT DIRECTOR, MANILA OBSERVATORY, PHILIPPINE WEATHER BUREAU

Everyone who reads this article—and no one can afford to miss it—will appreciate that meticulous accuracy in obtaining, keeping, and dispensing time is far from easy to attain.

Father Deppermann takes our readers behind the scenes at a great Observatory to show them how time is obtained from the stars. He tells them how and why it must be preserved with such great accuracy that it can be transmitted to others with an accuracy of at least one one-hundredth of a second. Each step has its own difficulties. The ingenious methods used to solve them show something of how scientists reason and work.

This paper will give you increased respect for "Father Time".

●

INTRODUCTION

One may be tempted to smile at the idea that, as "Father Time", I am worrying about the one-hundredth part of a second in this so-called "land of mañana", where one is inclined wrongly to think "it is always afternoon".

True it is that, locally, we rarely need time accurate to more than a minute. Furthermore, for ships at sea to fix their positions, the wireless broadcast of time, accurate to about half a second, is usually quite sufficient; but for geodetic work as well as for an increasing number of scientific purposes, time accurate to at least one-tenth of a second is imperative. In fact, for tracing the actual path of radio waves, for the determination of exact longitude, for the solution of the interesting question whether the continents are moving slowly relative to each other, and for many other problems, there is an insistent demand for time correct to at least the hundredth part of a second.

Few indeed, however, realize what a swarm of difficulties arise to prevent such accuracy. We have only to compare among themselves the corrections given by different first-class Observatories to their own signals with the corrections given the very same signals by other Observatories receiving them by wireless, to be convinced that, although such corrections are given to the *thousandths* of a second, and rightly so, we are really as yet none too sure of the *hundredths*.

We think that a brief survey of our own difficulties in maintaining accurate time will not only be interesting, but it will also give an insight into the principles and methods of scientific research.

We may group our considerations under three main headings: the *getting* of accurate time, the *keeping* of accurate time and the *dispensing* of accurate time. We shall take up each in order.

GETTING ACCURATE TIME

We accept the stars as our primary clocks or time keepers, considering as a "star day" (sidereal day) the difference in time between two successive passages of a star across the meridian, or north and south line, of our Observatory. Our problem now is to find out, to the smallest possible fraction of a second, the time a definite star crosses our meridian according to our own master clocks. But the *Nautical Almanac*, or *American Ephemeris*, gives tables allowing us to compute, correct to the thousandths of a second, just when a star should really cross our meridian. The difference between this value and the time of passage as given by our master clocks gives us our clock errors.

How do we check, however, our primary clock, the star, against our Observatory master clocks? Simultaneously, on a chronograph we record the seconds' beats of our master clock, and the time the star crosses the meridian. The chronograph has many forms, but in a simple, standard type, it consists of a drum with paper thereon, rotating constantly and uniformly, upon which a pen makes a continuous spiraling straight line except when interrupted by a kink exactly every second, produced by electrical connection with the master clock. So far for recording the clock; how about the star?

The passage of the star across the meridian is observed by a transit instrument. This is essentially a telescope which can be rotated, in the plane of the meridian, about a horizontal axis. It is set for the selected star. As this crosses the field of view either a key is tapped to make a kink in the chronograph record every time the star passes cross-hairs in the eyepiece, or else a movable crosshair is kept steadily on the moving star by turning a little wheel. As this wheel turns it repeatedly makes and breaks an electrical circuit, and thus kinks the recording line on the chronograph. Other newer methods for recording the star passage will be mentioned later.

This really sounds comparatively simple: star, transit, clock, chronograph. Can not these be easily coupled to give at least one-thousandths of a second accuracy? At present, the trouble in general is not so much with the master clocks or chronographs. It is with the transit. Let us examine this more closely.

Our old professor of physics at Hopkins, Dr. Pfund, used to say: "I will not be satisfied until you lose your respect for all the instruments in our laboratory!" By this he meant, that all instruments, like men, have limits of accuracy, and it was up to us to find that limit. So it is with the transit. It is all very well to say: All you have to do is to get your transit swinging in the meridian plane, and there you are! How do you know that the axis is really horizontal? How do

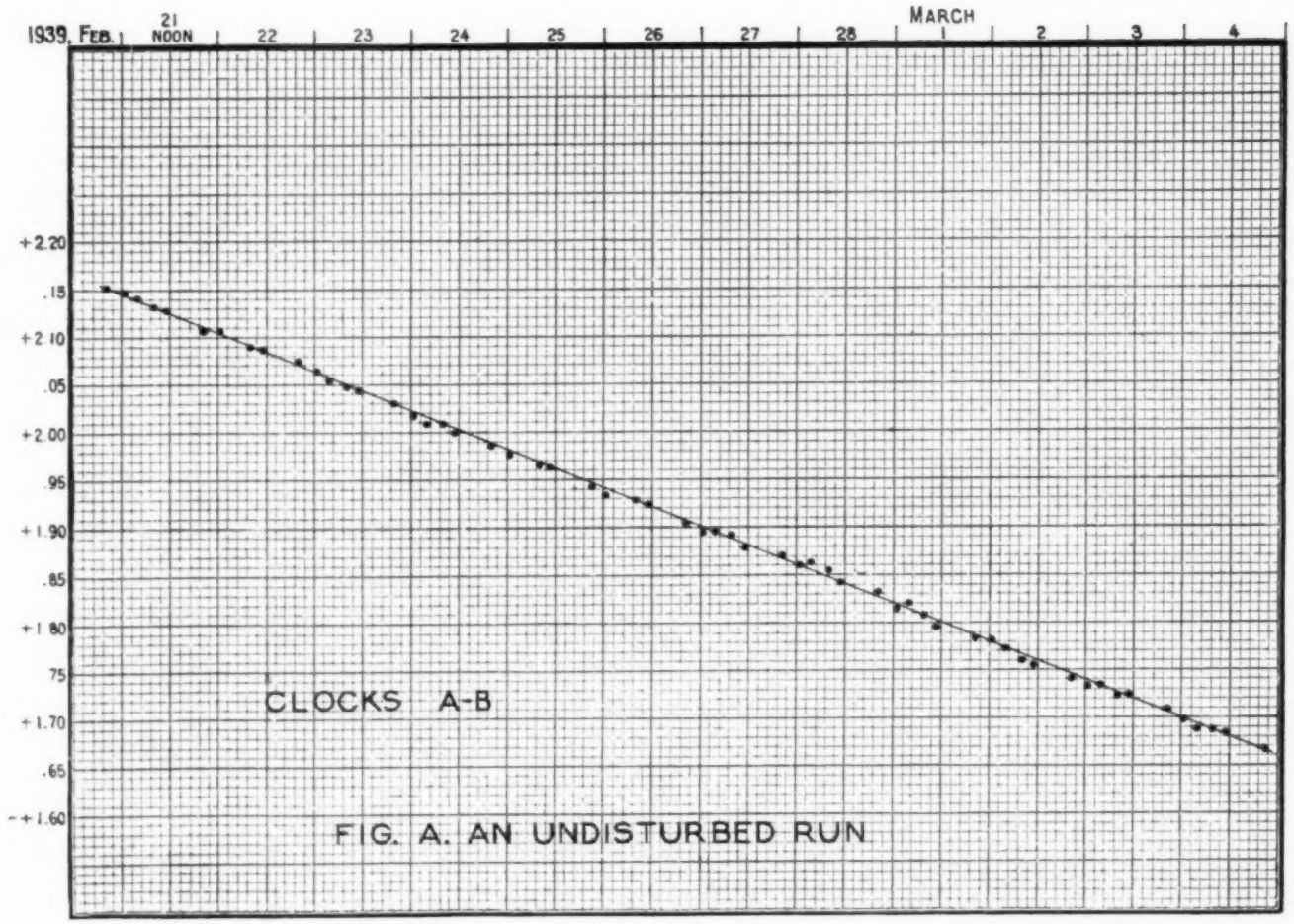


FIG. A. AN UNDISTURBED RUN

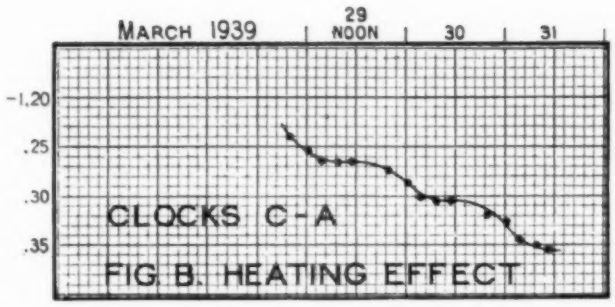


FIG. B. HEATING EFFECT

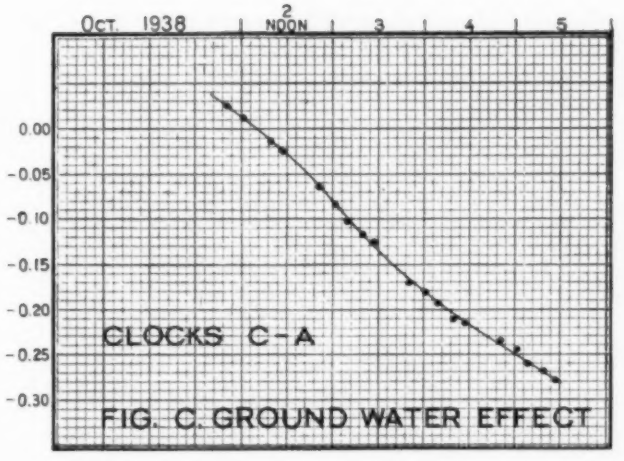


FIG. C. GROUND WATER EFFECT

you know that the objective lens of the telescope will send the light down perfectly perpendicular to the horizontal axis?

A little reflection will show that all these things are necessary if we are to get the transit of the star recorded on our rotating drum exactly at the time it hits the meridian plane. But can't you easily tell by a level if the telescope axis is truly horizontal? Now we have hit a sore point! Even delicate levels are tricky. They have to be very delicate indeed, if errors of hundredths of a second in our results are to be accurately avoided. Slight local temperature fluctuations, stickiness of the fluid of the level, actual inaccuracies in the interior curvature of the glass of the level; these and other things all combine to make the reading of the level to the required accuracy very doubtful. Here is truly a fine field for some ambitious scientist, to discover some new method, say by means of interference fringes, to level the transit more perfectly. Father LeJay, of Zi-ka-wei Observatory, Shanghai, China, is experimenting now with his gravity pendulum used as a level; the method seems promising, but it is too soon to give a final judgment on its practicability.

Then, how about the lens not sending the light down from the star perpendicular to the horizontal axis? Fortunately we can here use a trick; sometimes the best way to solve a difficulty is to avoid it altogether! Suppose the objective of the telescope sends the light down the telescope off perpendicular, and leaning towards the east. Since the star travels from east to west, it will be observed too soon. But let us now rotate the telescope around a vertical axis through 180 degrees, so that the part that pointed east now points west, etc. The light rays through the objective now lean just as far to the west as they did before to the east; in consequence the star is seen just as much too late as it was formerly seen too early. The mean of these two times should be correct, since the two errors, one too late, the other too early, now cancel each other. What we do, therefore, is first to observe the star by tap-key or moving cross-hair *before* it reaches the meridian, quickly turn the transit through 180 degrees around a vertical axis, and observe the star again, recording the kinks now in reverse order, *after* the star has passed the meridian. We then add corresponding kinks in the chronograph record, and divide by two, to get rid entirely of the otherwise very troublesome "collimation" error, as it is called.

But how is the third source of error calculated, that arising if the horizontal axis of the telescope is not pointing exactly east and west? If there is a clear space for a considerable distance north and south of the instrument, then by means of accurate astronomical observations, we can set up a "mire", or mark, very accurately north and south of the transit. By viewing this mark through the telescope at the time we are making our star observations we can compute the momentary deviation of the horizontal axis from exact east and west. But what if the view is obstructed, as in our own case, and no satisfactory "mire" can be erected? We have recourse to another subterfuge. As already stated, we got rid of the col-

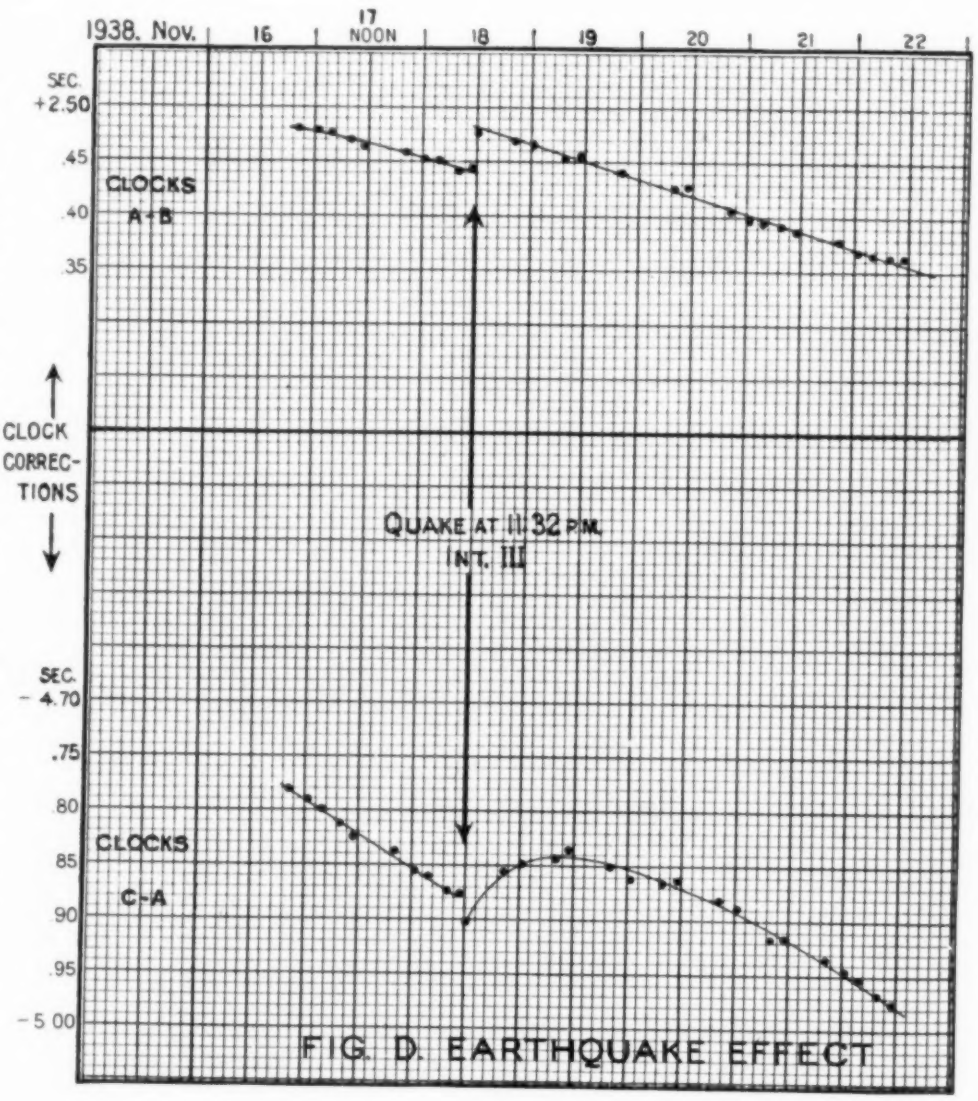


FIG. D. EARTHQUAKE EFFECT

limation error, and we know the level error by reading the level. We have left therefore two main unknowns: first, the actual clock error, and second, our "azimuth" (or East-West) error. These we can connect by an equation. Of course, one equation with two unknowns is indeterminate. But for many reasons we are not content to get the time from one star; we usually observe six to eight in a single complete program. Therefore, we can make up six or eight equations, each with the same two unknowns. By what is known as the method of least squares, it is now easy to get quite readily the best value not only for our azimuth but also our final clock error as well.

Still we are by no means through with sources of error. We must next consider our very fallible selves. Suppose we watch a star crossing a line in the eyepiece of the transit, and tap a key just as it does so, thus making a kink on our chronograph record. What is our error, our personal equation as it is called? You may be surprised to learn that even experienced observers may differ by some hundredths of a second from each other, and astounded to hear that some famous astronomers when getting old had a definite lag or tardiness in recording amounting to almost a second! You see it takes a short but quite appreciable time for a person to become aware of the star crossing the line, for the brain to communicate this to the hand and for the hand to respond by tapping a key.

It would not be so bad if this were always a constant, but it is actually a variable, not only between person and person, but also for the same person according as he feels fresh or tired, well or sick, hurried or at his ease. In fact, in attempting to get over this difficulty, some Observatories make the man on duty, —by following a fictitious laboratory star whose position and motion are accurately known,—determine his personal equation each night as he observes. But it is the writer's opinion that this solution is not ideal, since a true star often looks and acts quite differently from any artificial star, as we shall see later on. Is not the difficulty avoided by using an "impersonal micrometer," *i.e.*, by constantly keeping a moving cross-hair on the star, as already explained? This certainly is quite an improvement over the tap-key method, but with the ever-increasing accuracy demanded of "Father Time" it is found that even the impersonal micrometer is not truly impersonal, but each observer's variable personal equation must be found while using the so-called impersonal micrometer!

Why not cut the Gordian knot by bowing out the human element entirely and using a photoelectric cell to record a kink on the chronograph every time the light of a star strikes the cell at definite intervals through the clear spaces of a grid placed in the eyepiece end of the transit? This is being tried, but it is difficult to get a photoelectric cell sensitive enough, and with a sufficiently small and reliably constant lag. Humans are not the only ones that have reaction times!

Then there is photography. This has been experimented with for a long time. It now seems to be working very successfully at the Naval Observatory at Washington in conjunction with a zenith telescope. This type of telescope is definitely pointed towards the zenith once for all, and the stars are photographed as they cross the field of view. This type has the advantage that it gets rid of most of the troublesome transit errors, not only minimizing the ones already mentioned but also the further ones of possible flexure or bending of the telescope tube when placed off the vertical, the lack of perfect roundness in the pivots upon which the horizontal transit axis rotates, etc. But it has discouraging disadvantages for any but a very large Observatory. A big telescope is needed, and only special stars can be used that transit directly at one's zenith. The ordinary "ten day" stars, as they are called, whose positions are calculated in the *Nautical Almanac*, can not be used since almost all will be off the zenith. The calculation of positions for zenith stars suitable for one's own Observatory is too laborious for any but the very largest Observatories.

Instrumental errors, personal equation—do these exhaust our troubles in comparing our primary clocks, the stars, with the Observatory master clocks? By no means. Our own atmosphere is often a very troublesome factor. There are various degrees of "seeing". By this we mean that our atmosphere itself can greatly change the aspect of the star in the telescope. The star image can be so "mushy" or "smeary" that the true center of the star disc is much in doubt; on the other hand the image may be quite sharp, but almost "dancing a jig." Mushiness can often be very much reduced by stopping down the aperture of the objective. The image is thereby made sharper though at the same time fainter and larger, but the dancing remains. A transit of large aperture may cut down the dancing, but it may make the star image too bright for accurate following with the cross-hair. The smearing and dancing are caused: *(a)* by local heat waves close to the roof opening above the transit. These can be avoided by enlarging the roof opening and by not observing too soon after sunset; or *(b)* they are due to unsteady conditions in the atmosphere itself. Ripples in the free air due to cross currents acting like prisms, heat bubbles acting like lenses, sharp cold fronts, approaching cloud formations, all these make for poor "seeing" and may seriously disturb the accuracy not only of visual observations but even of photographic and photoelectric recording. For this reason, in getting time, reliance is not had on a single reading as a single star crosses the middle of the field of view of the transit. Usually eight or more cross-lines are placed in the field of view, or eight or more contacts made by the rotating wheel as it follows the star. Furthermore, not one, but some six to eight stars are observed, and the mean of all these observations taken to get a good value of the clock error.

But even all these precautions, at times, do not help if the "seeing" is really bad. Lately, the writer took time from the stars soon after a thunderstorm. As later observations showed, the error due to bad seeing

Continued on Page Eighty-three

Cosmic Rays (1900-1938)

● **By Dorothy Sugrue.** *Class of 1941*
MUNDELEIN COLLEGE, CHICAGO, ILL.

Miss Sugrue, a science major at Mundelein College, expended much time and effort in gathering together and sifting the ideas of important scientists concerning cosmic rays, what they are, where they originate, and how they are formed. The results of her search are embodied in this paper which was read before her class.

Unless they were otherwise informed, few of our readers would suspect that this article was written by a college sophomore. It is evident that the writer is not an "ordinary" student.

We are glad to call attention to such meritorious work.

●

Cosmic rays are electrified particles which constantly bombard the earth from every direction. It is estimated that about thirty shoot through every individual every second. They have energies higher than any particles ever propelled by man-made machines—energies in some cases measured in hundreds of billions electron volts.

The study of cosmic rays began in 1900 with the discovery by C. T. R. Wilson, and by Elster and Geitel, that the air in a closed vessel had a slight residual conductivity. The apparatus for these early experiments consisted of an ionization chamber. In its simplest form this apparatus consists of a metal box in which is suspended an insulated wire carrying a gold leaf; when charged electrically the movement of this leaf records the electrical conductivity of the gas in the box. With such a simple apparatus as this it was found that there was a residual conductivity of the air which could not be explained by the effects of the known radio-activity of the earth's crust, and which was probably due to the presence of some very penetrating radiation. In 1901, C. T. R. Wilson thought that this residual ionization might be due to some radiation coming from sources outside the atmosphere, either electromagnetic radiation like X-rays, or corpuscular rays like cathode rays, but of enormously greater penetrating power.

Since that time many theories have been proposed concerning the origin of cosmic rays. Some physicists have believed that they originate outside our own galaxy, while others have claimed that they have their origin in our galaxy. As yet we do not know exactly where they originate, but our knowledge of them is infinitely greater now than it was in 1900.

In 1932, Dr. Alexandre Dauvillier, of the Institut des Hautes Études of Paris, suggested the theory that extremely fast electrons coming from the sun with a speed practically identical with light are responsible for the origin of cosmic radiation.[1] This theory has also been suggested by Lord Rutherford who holds that the bright spots which are seen on the sun's surface are the source of these fast moving electrons. They represent regions where the temperature is 7000° Centigrade. Streaming out from these hot regions with relatively slow velocity, the negatively charged electrons are enormously speeded up as they pass through the positively charged atmosphere of the sun.

In 1933, Professor R. A. Millikan of the California Institute of Technology announced that cosmic rays are produced during the *formation* of atoms in interstellar space, and he has presented evidence that this is one stage of a cyclic process through which the universe is continually passing, assuming that cosmic rays are electromagnetic radiations or photons, similar in type to X-rays or gamma rays, but of shorter wave length.[2] In direct contrast with this is the theory of Sir James Jeans which holds that these rays result from the *annihilation* rather than the transformation of matter.[3] At the same time Abbé Lemaitre, Belgian priest physicist, believed that millions of years ago the universe was more concentrated than it now is, and that it started to expand with explosive violence, so that the distant nebulae continue to fly with ever increasing speed. At the time of this primeval explosion, he thinks, not only nebulae and stars were thrown out, but also atoms and electrons and photons. According to his theory it is these elemental pieces of the original world stuff, still flying around in space after thousands of millions of years, which constitute the cosmic rays.[4]

In 1934, Dr. W. Boade of the Carnegie Institution, Mt. Wilson Observatory, and Dr. F. Zwicky of the California Institute of Technology, stated that cosmic rays originated in the strange and rare phenomena during which stars flare up with sudden bursts of energy that make them shine as bright as the planets.[5] The special "erupting" stars are called super-novae. Super-novae stars are ordinary stars which blow up like a bursting shell with the velocity of expansion nearly that of the speed of light. Some stars in the process may lose over half their mass by radiating it into space. Visible and ultra-violet light are known to be emitted during the star eruption. It is suggested that cosmic rays may have been emitted at the same time.

Intense electrical fields somewhere in the universe were suggested as the most likely source of cosmic rays by Dr. Thos. H. Johnson of Barton Foundation. Speaking in 1935, he said, "Accustomed as we are to electrical displays during thunder storms and volcanic eruptions, it is easy to imagine similar processes taking place on stars. Negatively charged particles of dust or vapor high above the surface of a star could draw from

its atmosphere positively charged atomic ions and project them like the beam of a cathode ray oscillograph, into cosmic space. Nuclei of hydrogen and helium atoms, the principal constituents of stellar atmosphere, would thus become the cosmic rays."[6]

Dr. Arthur H. Compton of the University of Chicago, offered a drastic revision of scientific thought last summer. Dr. Compton formerly believed that the origin of cosmic rays was the remotest depths of space beyond the Milky Way. Last July he retracted this statement. He now believes that they come from within, not without the Milky Way—that they whiz around it inside like rats in a trap, imprisoned there by the gigantic magnetic field of the galaxy, while electrically neutral starlight escapes to the outside.[7] His reasons for the revision are twofold: first, he has not been able to find any evidence of the so-called "galactic effect" in the rays' intensity; second, after comparing all available data on cosmic ray intensities in relation to sidereal time, the results indicate that cosmic rays originate in the same galaxy of stars as that which contain the earth and sun. If the rays came from outside the local galaxy there should be some evidence of the earth moving appreciably with respect to the source of cosmic rays.[8]

Just as there have been many theories advanced about the origin of cosmic rays, so also there have been many concerning their nature. When Dr. Compton returned from his trip around the Western Hemisphere in 1932, he made two statements: One, that near the magnetic equator the intensity of the rays is less than near the magnetic poles, indicating that they are electrical in nature, rather than pure wave forms. The other, that as higher altitudes are reached the intersity increases, probably reaching a maximum at the top of the atmosphere. This is also held to be an argument against the pure wave theory.[9]

To account for the difference in the intensity of the rays at the magnetic equator and the magnetic poles, Dr. Compton pointed out that the earth is apparently acting as a huge magnet in relation to the rays. If the rays are electrified particles, the earth's magnetic field would cause them to bend away from the equator and to concentrate them at the poles. However, if they were uncharged, like light rays, they would not be affected by the earth's magnetic field.

Nevertheless, Dr. Millikan has opposed Dr. Compton's idea. He has steadfastly held that cosmic rays are not electrified particles but that they are photons. Abbé Lemaitre considers the commonest constituents of cosmic rays to be similar to alpha particles emitted by radium. Also, that beta particles or electrons must show latitude effect, which moreover seems to exist.[10] In this he upholds Compton's idea. But he adds that experiment shows a preponderance of cosmic rays consist of photons or radiations like light waves. This upholds the Millikan idea. However, the general trend among physicists today is in support of Dr. Compton's theory.

Professor Bruno Rossi, Italian physicist, as a result of experiments performed at Padova's Institute of Physics, says that cosmic rays are streams of particles, not electro-magnetic waves like X-rays or radium or gamma rays.[11] Moreover, his observations show that cosmic radiation at sea level is exclusively a corpuscular radiation. In concluding that primary cosmic radiation, which reaches us from outer space, is in all probability corpuscular radiation, he reiterates Compton's idea.

It has been observed that most of the cosmic rays are positively charged. This conclusion is drawn from the fact that intensity increases toward the magnetic equator, and that the rays are bent more toward the east. Professors R. A. Millikan and I. S. Bowen and Dr. H. Victor Neber, all of the California Institute of Technology, believe that the incoming cosmic ray electrons are charged with positive electricity because their conversion into cosmic rays is due to the annihilation of the cores of atoms containing only positive charges.[12]

In April, 1938, Dr. Robert M. Langer of California Institute of Technology, predicted that another particle having a mass of from two to ten times that of ordinary electrons should be found in cosmic radiation.[13] The new particle would be between the already discovered high energy electrons and the massive "X" particles. Also, that it would account for the cosmic ray effects noted in high altitude experiments.

The energy contained in cosmic rays is beyond calculation. Dr. Millikan believes that the total radiant energy in our galaxy in the form of cosmic rays is nearly the same as that in all other forms of radiation, such as light and heat emitted by stars.[14] The enormous penetration of the rays leads to the conclusion that the rays must be of immense energy. The gamma rays from radium, the most penetrating atomic rays previously known, can penetrate only a few meters of water. Thus the cosmic radiation is many times more penetrating and likely to be very much more energetic.

The intensity of the rays varies with height and depth. Recent work by Millikan and Regener has shown that at thirty kilometers above the earth's surface the rays are two hundred times as intense, and Regener has found that at two hundred eighty meters below the surface of Lake Constance the intensity of the rays is only about one per cent of that at sea level. Variation with time is not so pronounced. The soft components of the radiation do show an appreciable variation with the time of day, the maximum being at midday, but when the soft radiation is filtered out by means of thick lead screens, the remaining penetrating component is found to be almost constant.

Dr. S. E. Forbush of the Department of Terrestrial Magnetism of Carnegie Institution of Washington, believes that the world-wide variation of cosmic ray intensity can be explained by the presence of a great ring of electricity whirling around the earth far out in space.[15] The magnetic effect of the current in this ring of electricity plus the magnetic effect of the earth's permanent magnetic field, would be expected to have a result equivalent to an increase in the earth's magnetic field. Such an increase, in turn, would account for a decrease in cosmic ray intensity. Dr. Forbush explains that world-wide cosmic ray variation can be accounted

Continued on Page Eighty-nine

Deep Focus Earthquakes

• **By William A. Lynch, Ph. D.** *(New York University)*
PROFESSOR OF PHYSICS, FORDHAM UNIVERSITY

This article supplements the paper on earthquakes that was presented in the Science Counselor some time ago by Father Joseph Lynch, S.J. Both scientists are connected with the Fordham University seismic station.*

In this paper Dr. Lynch discusses the rarer deep focus quakes as distinguished from the more common shallow ones. Some major earthquakes occur as deep as 500 miles below the earth's surface.

The method by which the depth is determined is described.

Figures 1, 3, and 4 are merely descriptive; they are not drawn to scale.

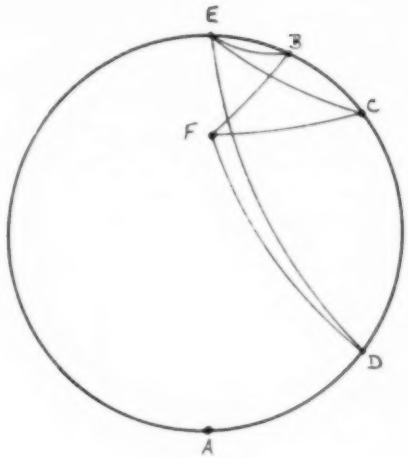


Figure 1

Seismology is comparatively new among the sciences. The first organized and concerted effort to study the causes and mechanics of earthquakes started with John Milne and his associates in Japan when they founded the Seismological Society of Japan in 1880. Many problems were solved by these early investigators, but one question that arose almost immediately, and for which they had no satisfactory answer, concerned the depth below the earth's surface at which earthquakes occur.

A threefold possibility suggested itself: (1) earthquakes are a surface phenomenon, the disturbance originating at or immediately below the surface; (2) they are centered in the crustal layers in which, geologists say, occur the continuous slow motions that accompany mountain building and ocean deepening; (3) they are disturbances arising deep down in the earth, hundreds of miles below the surface. Observations and theory led the later seismologists to believe that the second view is the true one for the great majority of earthquakes: they have their origin at a depth of about 25 kms. below the earth's surface. Shocks at this depth are now classed as "normal."

H. H. Turner, of Oxford University, came to the conclusion, in 1922, that a small percentage of the major shocks are deep focus earthquakes; *i.e.*, they have sources hundreds of kilometers below those of normal earthquakes. He reached this conclusion as a result of his study of earthquake reports submitted by seismic stations from all parts of the world for inclusion in the *International Seismological Summary*. His demonstration of this result is as follows: F is the focus of the earthquake, the true center of disturbance, Fig. 1. E is the epicenter, the point on the earth's surface vertically above the focus. (For normal shocks, focus and epicenter are so close together that their separation cannot be shown on a figure of this size; the figure is drawn for the case of deep focus to be discussed; the distance EF is the depth, exaggerated to show clearly the different paths possible.) B, C and D are seismic stations at epicentral distances (measured along the surface of the earth) EB, EC and ED respectively.

Turner's calculations for an earthquake of this type located the best epicenter at E; but then he found that for *rings* of stations between E and C (B is a station in such a ring), the calculated time of arrival of the earthquake waves was always *earlier* than the recorded time, the calculation being based on the assumption that E is the *epicenter of a normal quake*. For a ring of stations such as C at epicentral distance EC, the calculated time agreed with the observed time of arrival; while for stations beyond C such as D, the calculated arrival was always *later* than the observed.

Whenever a condition similar to this arises in the location of epicenters, the difficulty is usually resolved by movement of the proposed epicenter along the surface of the earth away from some stations and towards others. Here we see however that no change of position along the surface will accomplish the purpose. Turner proposed shifting the source of the disturbance downward to F far below E until the times calculated for paths such as FB, FC and FD agreed with those observed. This meant an increase in the calculated travel time to B, a decrease in that to D, while the travel time to C remained the same whether computed from E or F. In this manner, Turner arrived at depths of focus as great as 500 kms. below normal.

Seismologists were not prepared to accept Turner's findings, however, and as late as 1928 Professor B.

*How Earthquakes Are Recorded, Reverend Joseph Lynch, S.J., December, 1935, p. 9.

Gutenberg, now of California Institute of Technology, wrote that probably no earthquake was centered at a depth greater than 50 kms. below the surface of the earth. Additional evidence was produced in 1931, particularly by Scrase, of England, which strengthened Turner's view of great depth for certain quakes.

In order to understand Scrase's argument, it is necessary to describe briefly the appearance of the record of an earthquake as written at a siesmic station by a modern seismograph. Figure 2 is a copy of part of the seismogram, recorded at Fordham University, of the normal earthquake which occurred November 6, 1938, with epicenter off the eastern coast of Japan about 6900 miles away. The prominent features of the record, or phases as they are called, are indicated in the figure; P refers to the first preliminary waves, *undae primae*, PR_1 to the P waves reflected once at the surface of the earth, PR_2 to the P waves reflected twice at the surface of the earth, and M to the maximum waves. The P waves are compressional waves transmitted through the body of the earth, the M waves are surface waves travelling along the earth's surface much in the same way that ordinary water waves travel over the surface of a quiet pond. The amplitude of the surface waves in normal earthquakes is many times as great as that of the preliminaries. The second preliminaries, *undae secundae*, do not appear on the part of the record shown; they travel more slowly than P, are transverse in character, and are known as the S waves.

In the records of certain earthquakes occurring in Japan, in the East Indies, and in South America, it had been observed that P and S were large and sharply defined, that each was followed by prominent phases absent in normal earthquakes, and that the surface waves were very small or missing entirely. Scrase accounted for these characteristics in terms of great depth of focus. He argued that at great depths, the energy of the disturbance is converted almost entirely into the

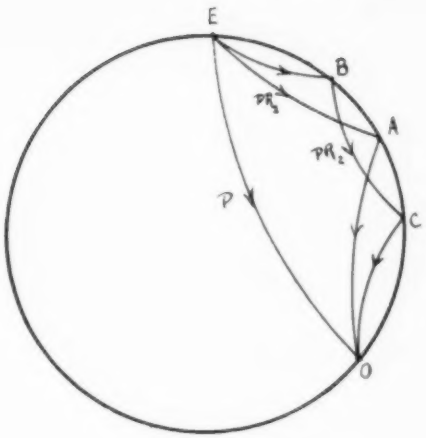


Figure 3

energy of the P and S waves within the body of the earth so that they are very strong phases; but that very little if any of the original supply of energy is available at the surface as surface wave energy. The surface waves are therefore very weak or entirely absent. He ascribed the new phases to reflections from the earth's surface of a type that had not been thoroughly investigated before.

To clarify this point, let us return for a moment to the case of a normal earthquake. In figure 3, O is a siesmic observatory recording a normal earthquake with E as epicenter; the focus is so close beneath E that it is not separately distinguished from E. EO is the path taken by the direct P wave. The curve is drawn concave upwards as the velocity of travel of the P wave increases as the depth increases. The equivalent of total internal reflection in optic occurs, and the waves that started towards the interior are refracted and emerge at O. EO may be treated as a seismic ray

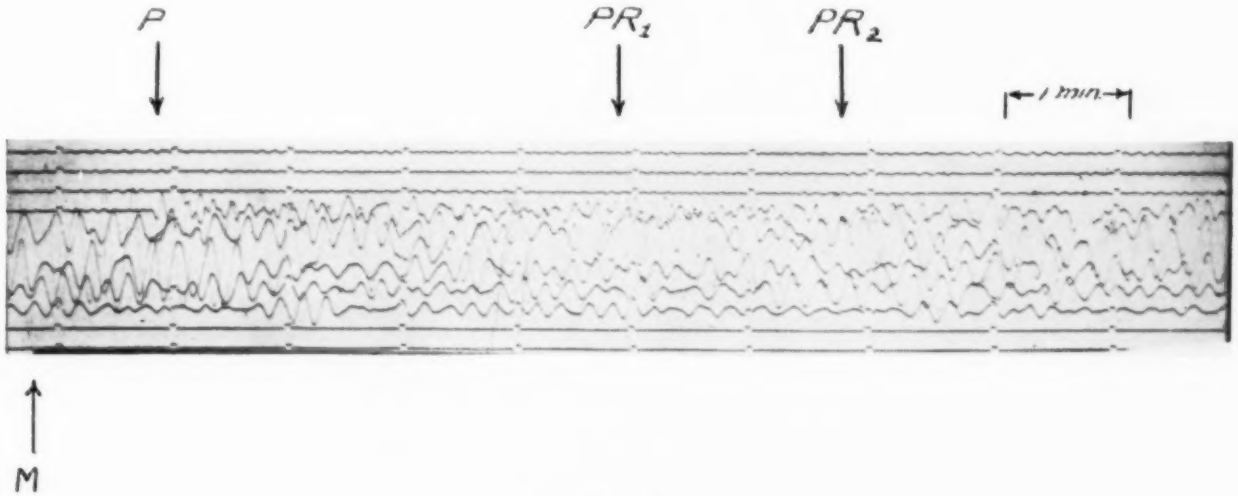


Figure 2

Japanese earthquake of Nov. 6, 1938. Epicenter 36° N, 144° E, depth normal (USCGS.) Shows many phases, particularly P, PR_1 and M. The distance between time marks on the record represents one minute; the horizontal lines are 30 minutes apart, so that M follows P by almost one hour. This record was written by the Galitzin vertical seismograph.

by the same methods as are applied to a light ray in optics. O may also receive a ray EAO which started as a P ray from E at a different angle from that of EO. It is refracted and reaches the surface at A, is reflected there according to the law of reflection, and is recorded at O as the phase PP or PR_1 (*i.e.*, a P wave once reflected.) O may also receive a PPP or PR_2, the P wave from E that is twice reflected, once at B and again at C, before reaching O.

These phases are shown in the Japanese earthquake of figure 2. The travel times of PR_1 and PR_2 at 6900 miles are about 4 minutes and 6 minutes respectively longer than the travel time of P, *i.e.*, they arrive these respective times after P at the observing station; this is seen to be the case in the Fordham seismogram. The difference between the arrival times of P and PR_1 increases as the epicentral distance increases until it reaches 6 minutes approximately, corresponding to an epicentral distance of 12,400 miles, half way around the earth. The difference between P and PR_2 is then about 10 minutes.

Scrase pictured two kinds of reflections occurring in deep focus quakes, the first similar to those of normal earthquakes and the second taking place close to the epicenter. Suppose F in figure 4 is the focus deep in the earth, E the epicenter and O the observatory. A seismic ray FO passes directly to O and is received as the first preliminary P. A second ray travels up to A, close to the epicenter, and is reflected to O where it is received shortly after P; it is designated as the phase pP. A third ray travels to C and is reflected to O where it is received as PR_1; it arrives after pP. The time of arrival of pP after P depends directly on the depth of focus and reaches a maximum value of about $2\frac{3}{4}$ minutes for a depth of 800 kms.

The ray FB leaves the focus horizontally; stations between E and B receive the direct P wave but no reflected waves; stations beyond B receive the direct P waves and both types of reflected waves. The same diagrams hold for the S waves as for the P waves so that there will be the reflected waves SR_1 and SR_2 in normal

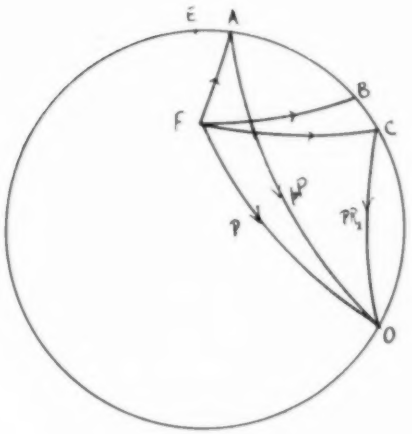


Figure 4

earthquakes and sS and SR_1 in deep focus earthquakes.

Having recognized these reflected phases characteristic of deep focus earthquakes, Scrase proceeded next to use them in determining the depth of focus. He saw clearly that for large epicentral distances such as EO, the length of the P wave path FO differs from that of the pP wave by approximately twice FA and that FA itself is very nearly the same as the depth EF; with this picture in mind he was able to make precise calculations of depths in terms of the arrival times of P and pP at different epicentral distances. His general findings have been applied to many cases of deep focus earthquakes since 1932 and seismologists are convinced today that major earthquakes do occur as deep as 800 kilometers or 500 miles below the surface of the earth.

Figure 5 is part of the seismogram written at Fordham on November 5, 1938. Its epicenter was in the same general location as that of November 6 but the focus was much deeper, being of the order of 100 kms. The phases P and pP, PR_1 and pPR_1 are clearly visible; the M waves are not as great in amplitude as in Figure

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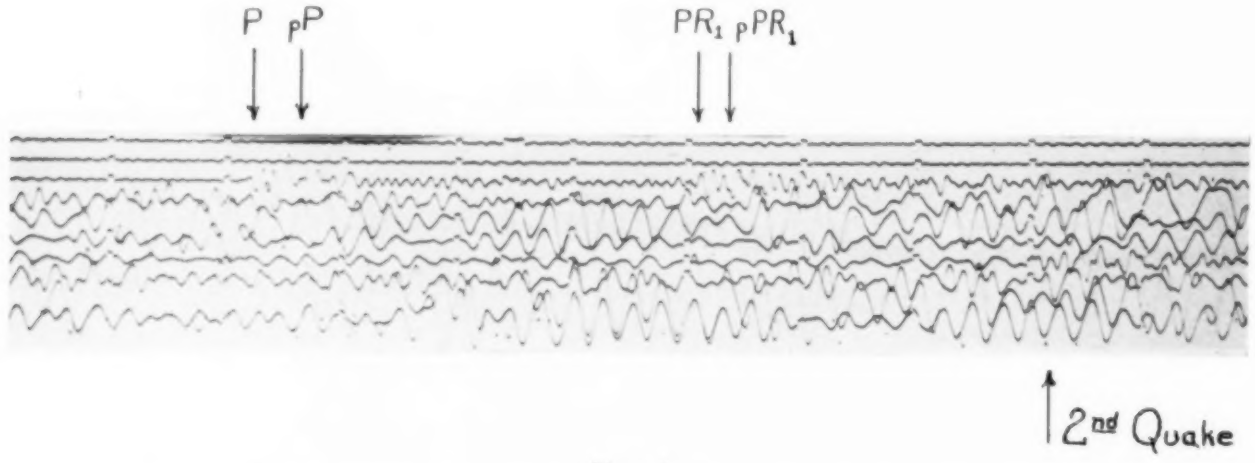

Figure 5

Japanese earthquake of Nov. 5, 1938. Epicenter 38° N, 141° E. Depth about 100 kms. Shows P, pP and PR_1, pPR_1. A second shock followed about two hours and seven minutes later. Record written by the Galitzin vertical seismograph.

Science Lessons and Life Problems

● **By Sister M. Geraldine Madden, R. S. M., M. A.,** *(St. Francis College)*
MOUNT ALOYSIUS JUNIOR COLLEGE AND ACADEMY, CRESSON, PENNSYLVANIA

Even though we may not be able definitely to evaluate them, in education transfer values are highly important. We know that the scientific method can be and should be of service in our daily living. Scientific principles as well as the facts of science find innumerable applications in the home. They provide a means of helping teachers adapt their teaching to the needs of their pupils.

Some of the best science teaching can be accomplished informally. An inspiring and efficient teacher tells here, incidentally, how she does it.

The writer's ideas on housekeepers and home makers will interest you.

●

To be of value, education must adapt itself to the needs of youth, both immediate and remote.

Watts, the artist, once said, "Education is at fault unless it leads to appreciation of new truth, new goodness, new beauty." A keen observer may note that this embodies the Scholastic ideal of Truth for the intellect, Beauty for the emotions, and Good for the will.

Now, how shall we apply this immediate and remote need of youth (particularly our girls), to the teaching of science in high schools?

It is sound psychologically as well as pedagogically to bear in mind the thought that a certain university professor stresses: In high school we are not training for specialization in the various sciences. Hence, the conscientious teacher of science, mindful that the majority of her girls will become home makers as well as housekeepers, will adopt a laboratory technique that will facilitate the achievement of her ends.

An efficient housekeeper centers her interest in feeding, clothing, and housing problems; while the home maker cares for the social, intellectual, and spiritual development of her family. The old contention that an education is wasted on those girls who expect to marry at an early age is rapidly losing ground, for thinkers admit that no one has more actual need of an education than does the real home maker. Consider what her knowledge must embrace:

She must know how to select, prepare, and serve foods which will meet the needs of a growing family. She must know how to choose and care for suitable clothing. She should have a knowledge of textiles, and an ability to make garments. She should know how to maintain a convenient, sanitary, and beautiful dwelling place.

Are not these knowledges and skills obtainable through the study of science? In assembling apparatus for an experiment, may not stressing the exactness and precision of the set-up, the loss in breaking equipment, and the economy of time, all help prepare the future home maker for her duty in life? Even so small a detail as the neat arrangement of well cleaned compartments in the chemistry laboratory may be a stimulus leading to desirable habits for the future.

The home maker must know how to care for children scientifically; how to budget her money in a way that will bring the best results. She must, above all, know how to organize and direct her work so that attention may be given to the aesthetic and spiritual development of the members of her household, without which no home can hope to flourish. Some may postulate that aesthetics, emotions, religion have no place in the laboratory or in science. But the Catholic teacher thinks otherwise. Every lesson is one in religion, a lesson in finding God.

Methods of procedure in the laboratory, if they are sufficiently flexible, will be the means of imparting, both directly and indirectly, other vital principles. For example, the very fact that each experiment must be written up with its Aim, Equipment, Manipulation, Observation, Computation (if quantitative), and Conclusion, is a potent factor in this regard. It is well, also, to stress the obligations of partners in an experiment so that one partner will not have to assume all the burden. The chemistry teacher may impart other useful lessons. Informal talks while washing test tubes or drying evaporating dishes should be encouraged. Such homely elements as iron, phosphorus, and calcium may be discussed.

Calcium is important in the blood, and determines the firmness and solidity of the bone. Iron is essential, because without it the body cannot make red blood cells. Phosphorus, in proteins, is vital to living cells. It is concerned with their multiplication. Phosphorus is a necessary factor in bones, and teeth, and the nervous and reproductive systems. Iron and calcium are found in rhubarb, dandelion greens, asparagus, and molasses; iron and phosphorus in egg yolk; calcium and phosphorus in milk and buttermilk. Why should we not teach that the source of iron for the body should be in spinach, cabbage, tomatoes, fish, oatmeal, carrots, peas, fresh fruits, and dried fruits such as dates, figs, prunes, and raisins, rather than in medicine? Phosphorus is found in cheese, egg yolk, cocoa, peanuts, almonds, walnuts, beef, beans, oatmeal and whole wheat. Calcium is found in oranges, milk, celery, dried beans, greens, and Boston brown bread. For the elimination of waste certain laxative foods are useful; for example, apples, bran, cabbage, celery, cucumber, lettuce, squash, tomato and turnip. Without a special course in dietetics the future home maker, merely through inciden-

tal learning, may assimilate much valuable information about foods.

Every experiment in the physics laboratory may be planned with a view to its application in later life. Without going into detail, we might consider the topics Light and Color. Not only the scientific details such as wave length, reflection, refraction, angles of incidence and reflection, candle powers, solar spectrum, etc., should be taught, but also the aesthetic and spiritual implications.

Because color is not understood, it is frequently either overdone or else utterly ignored. No one fails to react to color, agreeably or otherwise. Is it irrelevant to emphasize what a gift from God is color, and how drab would be existence were there none? Why does a certain color scheme have interest and individuality? Is it always the result of study, and of a keen appreciation of both its scientific and its aesthetic implications? Since our girls are to be home makers, it would be well to call attention to the fact that cool colors are not for northern rooms which lack an atmosphere of warmth, but for warm rooms flooded with sunlight. We are all conscious of color in clothes. As background, too, it plays an important part in our daily lives. So, in the physics laboratory in the "spare" moments when we are arranging apparatus, screwing in the various types of lenses or arranging prisms and the minds of students are apt to wander, it is wise to plan a discussion, informal of course, on the importance of light and color.

We can show how color arrangements may be inspired by various factors, autumn leaves, a beautiful painting, a rare piece of pottery, a graceful arrangement of furniture, or even the simple experiment on the dispersion of light. The different values of the hues forming the keynote of a room may be discussed. Shades of green may be olive, jade, or the surf green so frequently seen in curtains. To use only one of these colors throughout would be to lose all distinction in a deadly, monotonous picture.

Color is not to be ignored on the table any more than in one's dress, or garden or home. Colors that clash should be avoided wherever possible. In foods they do not usually appear together except, perhaps, in the serving of left-overs. Beets and carrots have decorative value. When we consider the color possibilities of other vegetables and fruits, we should have no difficulty in avoiding anything out of harmony with the general scheme. Perhaps only artistic souls revel in garnishes, but when used discreetly they add much to the beauty of the meal. Attractive linen, colors that please, bouquets of flowers, may transform into a real banquet such dishes as boiled beef, potatoes, and parsnips.

In illustrating the principle of the camera and of the eye, there is ample opportunity for the interested teacher to stress spiritual values. If the image impressed upon the retina is not erect, why do we not perceive objects inverted? Such a question may start a flood of queries in the mind of thoughtful students. Both subjective and objective elements may easily be taught. Elementary psychology is essential here.

The concept formed by the intellect depends not merely upon the external stimulus, but also upon inherited capacities, acquired skills, former training, and previous acquaintance with the object. If we look for beauty, we can find it; if we seek evil, we miss the good. The value of the visual image, as compared with other types, auditory, tactual-motor, olfactory, gustatory, in the formation of character may be noted in passing; the danger in attending objectionable moving picture plays; the harm in sex-education by means of visual aids; the need for storing in memory numerous and varied phantasms, so that in the genesis of a concept the mind may be more enriched.

The real home maker will come to realize that there are some problems in life that cannot be solved by even the most skillful scientific technique. What then?

Let us consider for a moment the great need for God in the world of today, noting what happened to those ancient civilizations that tried to attain lasting splendor apart from the Creator of the Universe.

As we look back through the centuries before the Christian era, we observe that men were striving to bring the forces of nature to their service, to adjust themselves to the conditions of their environment, to improve the individual and social life of the times, and to live either in union with the one true God, or in contact with the many deities of mythology. Civilization after civilization reached a certain zenith of life, culture and power, only to degenerate and collapse. Men sought freedom, happiness, and life, but they found enslavement, sorrow and death. Today, scientific expeditions, digging in the graveyards of these ancient civilizations, uncover decaying remnants that mutely testify to the weakness of a life lived without God.

Due in part to the advancements of science, the efforts of many peoples over a long span of years eventually resulted in progress. Now there is scarcely anything from the lightning that flashes through all the windows of the sky down to the minerals in the hearts of the mountains or on the floors of the seven seas that man has not captured, imprisoned and pressed into service. With all the tremendous power that science has given man there is danger, for unless one lives securely entwined with the divine life of God, he will be led astray from the sane dictates of natural reason to seek development in the mirages of worldly sufficiency and material prosperity.

It may be asked, what is the scientific implification?

There is a menace in teaching scientific principles apart from religion. No matter what strides the scientist makes, without God he remains aloof from the source of life. The inevitable result is that scientists become immersed in the material and transitory things of the world and indifferent to union with God in religion. They become content with a devitalized Christianity or a modern form of paganism. This spirit can infiltrate our western civilization so insidiously that selfish indifference to the security of human society and the inhuman spirit of ultra-individualism will prevail.

Without God and the recognition of spiritual values what a chaotic world this would be! If selfishness and

Continued on Page Ninety

How Ferns Grow

● **By W. N. Steil, Ph. D.** *(University of Wisconsin)*
HEAD, DEPARTMENT OF BOTANY, MARQUETTE UNIVERSITY, MILWAUKEE

Those who appreciate the beauty of the many species of native fern, so common in our woodlands and swamps, will be glad to learn how these seedless plants come into existence, and how they live and grow.

As fully as he may in so brief a paper, Dr. Steil describes the plant, root, stem, foliage leaf, and frond with spores. He discusses the spore and the nature and function of the structure produced as a result of its germination.

This important paper by a distinguished botanist will both interest and instruct.

●

INTRODUCTION

Ferns grow in every climate and in nearly all conditions of environment. Certain species grow in water, in swamps, in sandy areas and on bare rocks exposed to the hot rays of the summer sun. Some species even grow on mountains thousands of feet above sea-level and almost inaccessible to the fern student. The woodlands, the swamps, and the cliffs are the most common and the most familiar haunts of the ferns. Although seed plants excel all other plants in beauty of their flowers, the ferns hold the palm for beauty of foliage.

The ferns comprise about 6,000 species and are a most varied group in form of plant body, size, structure, and life history. To write only the story of how ferns grow is such a great task that one can hardly do justice to the subject in a brief paper such as I shall write.

THE ASEXUAL GENERATION (THE SPOROPHYTE)

I shall begin our story with a brief description of the familiar bracken, botanically known as *Pteridium aquilinum*, probably the most generally distributed fern, and best known to most persons as the woodland and roadside bracken. It even grows in fields and is then considered a weed.

A fern like the brake, in common with all other typical ferns, possesses three plant organs—leaf, stem, and root (Fig. 1). Hence ferns differ from the higher plants which also possess flowers, fruits and seeds.

The Foliage Leaf

The ordinary leaf of the brake grows, sometimes, to a large size, exceeding occasionally in height that of a man. The leaf is the only part of the fern above ground, the stem being completely buried a few inches below the surface of the soil. The leaf-stalk, or petiole, supports the expanded portion, or the blade, which, as shown in the figure is triangular in outline and is divided into three parts or leaflets, each of which is again divided into parts known as pinnules. The latter are only partially divided as can be readily observed from figure 1.

The veins of the leaf are interesting since they are forked (Fig. 2). This kind of forking or branching of the vein, or dichotomy, is a distinguishing character of ferns.

That the structure of a fern leaf is similar to that of a seed plant can readily be seen when a study of the leaf is made. When the lower surface or epidermis is removed with a scalpel, mounted on a slide, and examined with a microscope, the numerous stomata with their dark green guard cells, and the ordinary epidermal cells can be observed (Fig. 3). The resemblance of this epidermis to that of the sunflower is close indeed. In a cross-section of the leaf, the upper portion, or palisade region just below the upper epidermis, and the spongy tissue which is the remainder of the green portion can be seen (Fig. 4). It is not difficult to distinguish the palisade region from the spongy tissue, but the line of demarkation between these regions is not so sharp as in the typical leaf of the seed plant. None of the numerous veins of the leaf are represented in the figure.

The importance of the foliage leaf is known to every student of plants. This organ is primarily concerned in the process of photo-synthesis by means of which two raw materials, carbon dioxide of the air absorbed by the leaf and water brought to the leaf from the soil, are combined under favorable temperature and light conditions to produce the basic food, the carbohydrate, like sugar and starch. From the carbohydrate, the fats, also necessary for the life of the fern, are produced. As the result of chemical changes in the basic food and with the addition of certain elements in salts derived from the soil, the proteins are formed. These proteins constitute the living substance, or protoplasm of the cells of every portion of the fern plant.

The leaf is also the principal organ by means of which the water is given off by the plant in the form of vapor.

It is in the leaf that much of the respiration of the bracken takes place. It must be kept in mind, however, that every living cell of the plant is concerned in this energy producing process, the importance of which cannot be over-emphasized in any plant, including the fern. Without this process, there would be no energy for the manufacture of food, digestion, conduction, cell and tissue formation, assimilation, growth and reproduction.

The Frond

In late July or early August, practically every brake will bear leaves which are somewhat different from the ordinary foliage leaves. These can be readily distinguished by the brown margins on the under side. These margins are formed by an infolding of a small portion

of the leaf (Fig. 5). When the margin of the frond is examined with a hand-lens, small, slightly brownish, nearly globular bodies known as the spore sacs can be observed. Only a small number of these, however, are visible, since most of them are completely covered by the small portion of the leaf which has been folded over in its growth to protect the sacs which contain the microscopic spores. This protective covering formed by the margin of the leaf is known as the indusium.

If, with a scalpel, a small number of the sacs are removed from the leaf and examined with a microscope, their structure can be studied. The spore sac is a somewhat flattened body, attached to a narrow stalk of considerable length (Fig. 6). It is by means of the stalk that the sac is joined to a portion of the leaf just inside of the margin, where it is connected by means of small veins to the main part of the leaf. The margin of the leaf to which the spore sacs are joined is known as the placenta.

The sac, as has already been stated, is a somewhat flattened, nearly globular case with a wall of one cell layer in thickness. The wall is composed of three kinds of cells. The cells of the flattened portion are large thin-walled, and polygonal in surface view. Along one edge of the sac is a single layer of cells in a definite row and extending from the base of the sac to about two-thirds of the way around. All of the walls of these, except the outer ones, are thickened and frequently highly colored yellow or orange to an almost red. This row of cells is known as the annulus, which is concerned in the mechanism of the discharge of the spores. Extending to the edge of the spore sac and on the opposite side of the annulus are two elongated cells parallel to each other and which may be observed on either flattened side of the sac. These are the lip cells.

Inside of the sac are the small somewhat rounded light brown spores (Fig. 7), sixty-four in number. Each spore consists of a rather thick wall and a protoplast containing dense cytoplasm including a few plastids and a single nucleus (Fig. 8).

The spores are produced from large cells in the spore sac, known as spore mother cells, sixteen in number in the brake. These cells each containing abundant cytoplasm and a large nucleus, are destined to divide twice and produce four spores which for a time remain together in a group, or a tetrad. There are thus produced in each sac 64 spores, as has already been stated.

When the mother cells divide twice, their nuclei undergo divisions which are different from the divisions which take place in the nuclei of the ordinary vegetative cells. The material substance of the nucleus is organized in a definite number of rod-like structures known as chromosomes. In ordinary nuclear divisions, these are divided lengthwise and separated into two groups and hence the daughter nuclei receive the same number of chromosomes possessed by the ordinary mother cell nucleus. When the spore mother cells, however, divide, their nuclei undergo a reduction of their chromosome number, and hence the spore contains only one half, or the haploid number, of chromosomes as the spore mother cell nucleus which contains the double, or the diploid number.

When the spores are ripe, they are gradually discharged from the sac. The manner in which the spores are set free has been observed by many botanists. Hence a brief description of the process may be interesting.

It is easy to observe the discharge of the spores under the microscope. Unopened spore sacs mounted on a slide in a drop of water over which has been placed a cover-slip are first located with the microscope. A drop of glycerin is then placed at the edge of the cover-slip. When the glycerin has mixed with the water, the solution will withdraw the water from the cells of the annulus and the tension set up in the cells will cause the

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DESCRIPTION OF FIGURES

Plate on page Seventy-seven

Most of the drawings are diagrammatic and are not made to scale. Figure 1 was prepared under the direction of Mr. Albert Fuller, curator of the Milwaukee Public Museum. Figure 10 was drawn by Mr. Harold Joseph, a graduate student in the Department of Biology of Marquette University.

Fig. 1. The brake (pteridium aquilinum). The fern plant showing the rhizome, the roots and the three-parted blade of the foliage leaf.

Fig. 2. A small portion of a leaf, highly magnified, to show the forked venation (dichotomy).

Fig. 3. A small portion of the lower epidermis of the leaf showing a few cells and a stoma.

Fig. 4. A small portion of a cross-section of a leaf showing upper epidermis mesophyl and lower epidermis.

Fig. 5. A portion of a frond showing the margin which has folded over the edge of the leaf where the spore sacs have been formed.

Fig. 6. A spore sac of the fern showing the stalk and the nearly globular portion containing the spores. The annulus, all the cell walls of which are thickened except the outer ones, is represented as extending about ⅔ of the way around the edge of the somewhat flattened spore sacs. The two elongated cells parallel to each other, known as the lip cells, the ordinary parenchyma-like cells and some of the outlines of some spores are also shown.

Fig. 7. A mature spore of the fern showing the outer reticulate surface of the wall.

Fig. 8. A spore shown in section. The large nucleus, dense cytoplasm and a number of plastids are represented in the figure.

Fig. 9. A cross-section of a rhizome showing two woody strands heavily shaded in the figure, numerous vascular bundles and the ground-work, the parenchyma. The outermost portion, represented by a line, is the epidermis.

Fig. 10. A cross-section of a vascular bundle showing the large heavy-walled vessels of the wood, or xylem at the center. Just outward from the xylem is the phloem, the food conducting portion of the bundle. The outer layer of cells is the endodermis. Between it and the phloem is the pericycle.

Fig. 11. A cross-section of a root. The innermost and shaded portion is the xylem, which is surrounded by a narrow zone of phloem. The parenchyma is the unshaded portion of the section.

Fig. 12. An early stage in the germination of a spore. A single green cell with a rhizoid.

Fig. 13. A short green filament produced by a germinating spore.

Fig. 14. A young prothallium formed from the filament. The proximal flattened end has produced an apical cell, somewhat triangular when viewed from the upper or dorsal surface.

Fig. 15. A mature prothallium as observed from the ventral surface. The cushion, which is shaded in the drawing bears the archegones. The posterior portion bears the antherids and the rhizoids.

Fig. 16. An antherid showing the proximal lid cell and the two ring cells below. Inside of the antherid are the sperms or the antherozoids.

Fig. 17. An antherozoid showing the heavily-shaded, rod-like nucleus, and the cytoplasmic portions including the numerous hair-like cilia.

Fig. 18. An archegone showing the enlarged portion, the venter which contains the egg, and the neck which contains slime. In the lower portion of the neck two nuclei are shown.

Fig. 19. A ripe archegone which has opened and discharged much of the slime. Numerous antherozoids are in the archegone and in the slime.

Fig. 20. A young embryo in the quadrant stage.

Fig. 21. A young fern plant and the gametophyte on which it has been formed. In the figure are shown the first leaf, the root, and the stem which is a small projection between the petiole of the leaf and the prothallium. The foot, which is embedded in the gametophyte, is not shown.

Fig. 22. A prothallium which is producing secondary prothallia.

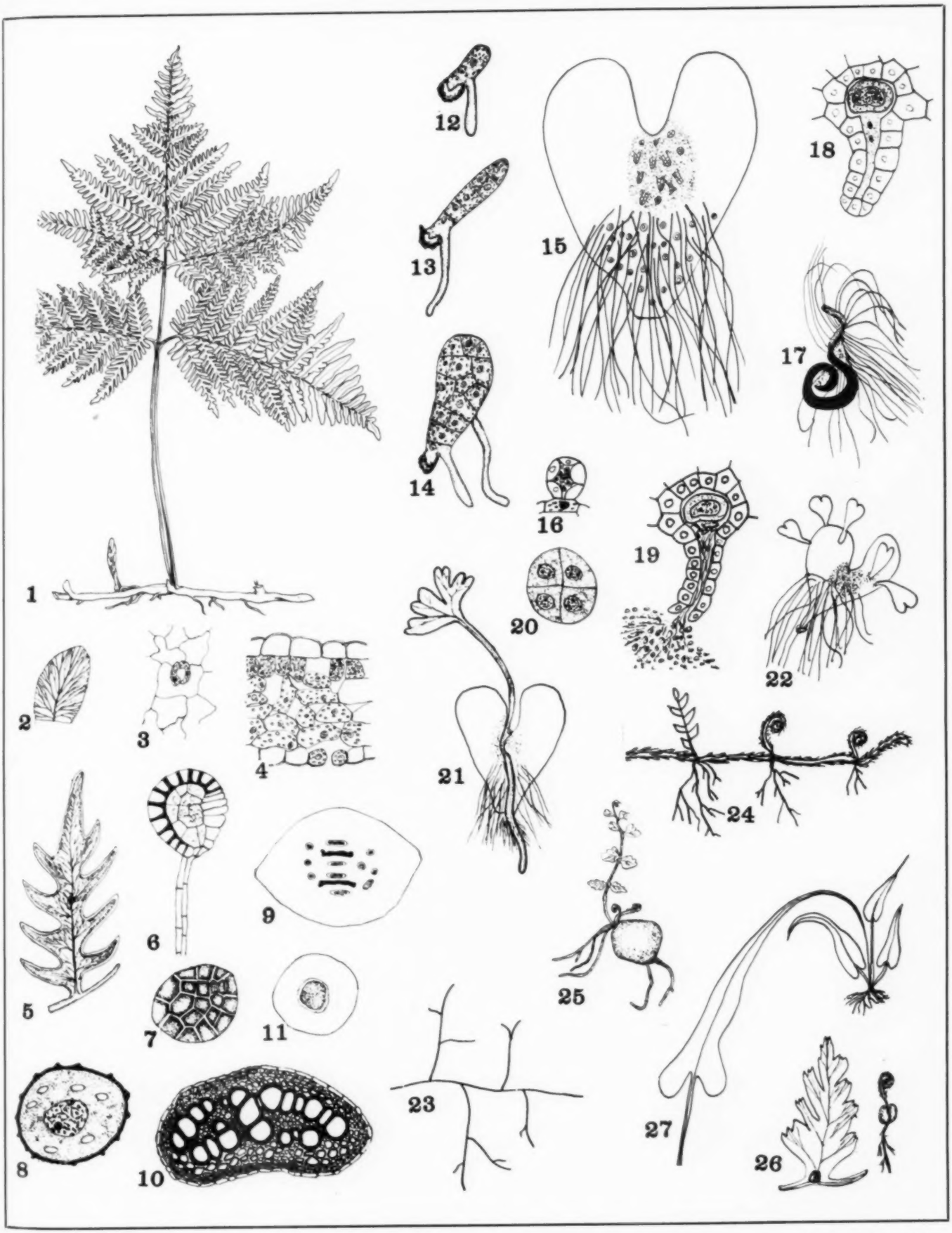
Fig. 23. A diagram showing the manner of growth and branching of the fern rhizome.

Fig. 24. A runner of a Boston fern showing the young fern plants which have been produced.

Fig. 25. A germinating fern tuber of one of the Boston ferns.

Fig. 26. A portion of a leaf of a bladder fern bearing a bulblet and a germinating bulblet.

Fig. 27. The walking fern showing the formation of new plants from the tips of the leaves.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annulus to turn backward and open the spore case, the separation taking place between the lip cells. When the annulus reacts and the case opens, the walls of some of the ordinary cells are often broken. One can also observe that the annulus sometimes becomes almost inverted when the sac opens. Then, however, only some of the spores will be discharged. If the glycerin solution is removed and water is added, the cells of the annulus will again absorb the water and very suddenly the case will close again. A number of spores are then discharged and perhaps the larger number of the spores which still remained in the sac. By repeating the experiment several times all of the spores are finally set free. In nature, with changes in the humidity of the air, the spores are discharged. They are often actually "shot" into the air as described above and for a distance of several feet. Since the spores are very light they may be borne by air currents or wind.

The color of the spores of the brake, as has been stated, is brown. The brownish appearance of the margin of the frond is due to the color of the spores in the nearly transparent spore sacs. In some ferns they are of a brilliant green, a red, a yellow, an orange, a black, or an almost white color.

In many ferns the spore producing leaf, or frond, may form numerous spores. Since a plant may bear mostly fronds, the number of spores produced by a single plant is, indeed, very large, frequently many millions.

A familiar observation of the nature lover in early spring, after the ferns have had a long winter's rest and have resumed their growth again, is the uncoiling of the leaf. This uncoiling leaf is commonly known as the crosier or fiddle-head. This peculiar crosier is another of the distinguishing characteristics of the ferns.

Before the leaves appear above the ground, nature has already determined that some shall be just foliage leaves and others fronds, which like ordinary leaves have not only a nutritive but also a reproductive function since they produce the spores, the importance of which in the life of the fern shall be discussed later.

The Stem

The stem of the brake may grow more than a hundred feet in length but seldom more than one-half inch in diameter. It is somewhat flattened, as shown in a cross-section (Fig. 9). Usually it contains much stored food in the form of starch. This horizontal stem, or rhizome, possesses an apical or growing end, and produces many lateral branches, as well as the roots and the leaves which are always borne singly.

When a cross-section of the stem (Fig. 9) is studied, the tissues can be readily identified. The outer single layer of cells is the epidermis. Almost in the center two heavy woody strands of a reddish black color can be seen. These portions give strength to the stem. A number of vascular bundles which conduct food and food materials are arranged about the woody strands and form almost a cylinder. Some bundles are also between the woody portions. Every bundle consists of an inner portion with large xylem vessels and an outer portion known as the phloem. The parenchyma serves as a groundwork for the other internal tissues of the stem and stores most of the food for the fern plant. A growing zone, or cambium is absent in the vascular bundle (Fig. 10). Hence, it is easy to understand why the bracken stem cannot grow to a large size.

The Root

In form and in internal structure the root of the fern as observed in a cross-section (Fig. 11) is similar to that of a seed plant with a central cylinder of wood surrounded by the food conducting phloem. Between this portion of the root and the epidermis is a region of cells, mostly thin-walled parenchyma cells, which serves to store food.

The root also lacks a cambium and, hence, like the stem its growth in thickness is limited. The root also possesses a growing end and hence resembles, in this respect, the stem.

Since the plant possesses the special growing ends or tips in both root and stem, it is evident that the bracken fern never dies a natural death—one which comes to it on account of age. Often, no doubt, the brake which grows in the woodland may be older than the oak in the partial shade of which it may be growing luxuriantly.

It is the root, needless to state, which by means of the tiny root hairs absorbs the water and salts in solution from the soil and which are so important to the life of the plant.

THE SEXUAL GENERATION (THE GAMETOPHYTE)

We have so far discussed only that part of the fern which to most persons is known as the plant. The plant with stem, root, foliage leaf and frond with spores has been described in considerable detail. Now I shall discuss the spore and the nature and function of the structure produced as a result of its germination.

The spore under favorable conditions germinates in about three days. The wall of the spore breaks open and a green projection and a colorless rhizoid emerge through the opening made in the wall (Fig. 12). The green cell soon divides at right angles to its length and as a result of further division of these cells, a short filament is produced (Fig. 13). Then divisions in a plane at right angles to these divisions occur in some of the cells at the proximal end. A plate of cells is thus formed at this end and in the center a cell known as the apical cell, triangular in surface view, is differentiated (Fig. 14). It is through the activity of this cell that the plate owes most of its further growth as well as its heart-shaped form. The structure, known as the prothallium, is the sexual generation or the gametophyte (Fig. 15). When mature it is almost one-fourth of an inch in diameter. It is only one cell layer in thickness at the margin, but often several layers in thickness just back of the apical notch. This thickened portion, known as the cushion, projects or bulges out on the ventral surface of the prothallium. The upper or dorsal surface is flat and bears no stomata or outgrowths.

The ventral surface of the mature prothallium, or gametophyte, bears three kinds of structures.

Continued on Page Eighty-seven

A Conductivity Kit for Fifty Cents

• **By Walter S. Lapp**
NORTHEAST HIGH SCHOOL, PHILADELPHIA, PA.

Teachers who must economize on laboratory budgets are continually on the watch for new ways of improvising apparatus. They become "gadgeteers". This practical paper by Professor Lapp will help them.

Here he describes a simple and inexpensive assembly that can be made to serve for a number of experiments. It works surprisingly well. The handy student can make it for himself.

Professor Lapp presented this paper at the annual meeting of the Pennsylvania Academy of Science that was held at State College in April, 1939.

CONSTRUCTION

A simple, inexpensive conductivity apparatus for individual student use can be assembled from the following materials:

2 feet rubber-covered lamp cord
1 No. 10 rubber stopper
1 attachment cap
1 cleat porcelain receptacle
1 candelabra bulb
2 inches No. 14 copper wire
2 4/36 x 1¼" machine screws
2 Mueller alligator clips
2 pencil leads or light carbons

All these materials may be obtained in electrical, radio, five-and-ten-cent, or hardware stores, with the exception of the rubber stopper, which, of course, can be obtained from a laboratory supply house. The entire kit should not cost more than forty or fifty cents. It is the writer's belief that this conductivity kit is less expensive and just as satisfactory as any such apparatus sold by dealers.

Figure 1 shows the manner in which the apparatus is assembled. Figure 2 shows how a conductivity test is made. The apparatus is supported by an ordinary burette clamp attached to a ring stand. Figure 3 shows how the apparatus should be held when raising or lowering it on the stand.

The student should grasp the attachment cap or plug itself, whenever inserting or removing it. The plug should never be removed by pulling the wires leading to it.

ELECTROLYTES AND NON-ELECTROLYTES

We begin our study of dissociation by having each student test the conductivity of dry sodium chloride, distilled water, and a solution of sodium chloride in distilled water. The same procedure is

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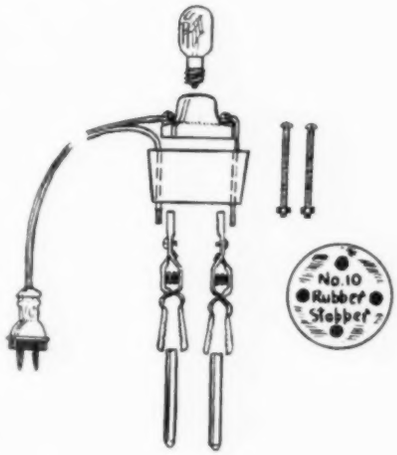

Figure 1

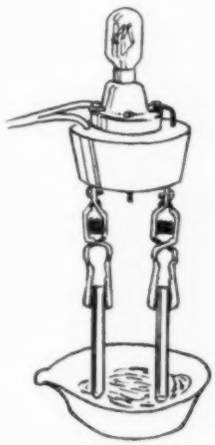

Figure 2

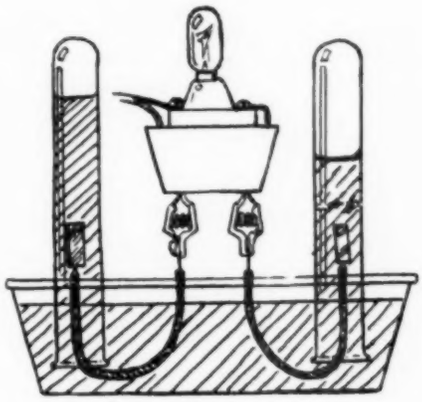

Figure 5

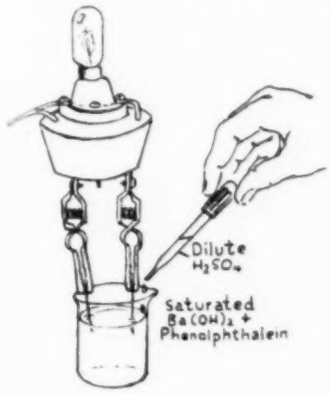

Figure 4

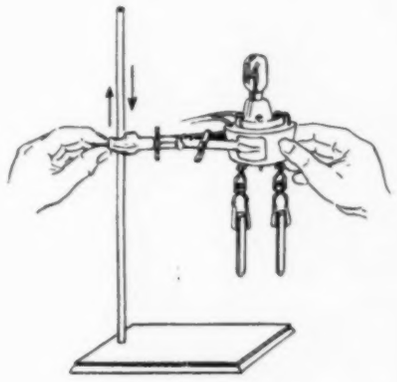

Figure 3

On Classical Training For a Career in Science

• **By William T. McNiff. A. M.** *(Fordham University)*
DEPARTMENT OF PHYSICS, FORDHAM UNIVERSITY, NEW YORK CITY

A number of years ago, men preparing for careers in science underwent the same preliminary training as those preparing for theology, law, or medicine. A knowledge of the classical languages was essential.

Now Latin and Greek are no longer generally required for college entrance. To some educators the utilitarian value of these languages is not clearly apparent. French and German seem to be more "practical."

Professor McNiff realizes that the engineer, the chemist, the physicist, in fact all scientists, should have a knowledge of the ancient languages. Since technical schools can give but a limited cultural training, he recommends that a knowledge of both Latin and Greek be required of all who expect to make science their life work.

Do you agree with him?

●

At a time in educational affairs when the stability and even the very structure of long established institutions and systems are being seriously challenged by forces of destruction and ignorance, it seems necessary for the promotion of social well-being that the attacks of all challengers should be met fairly and formidably. It is the object of this writer to meet here the challenge of those who argue for the elimination of any requirement of classical knowledge in the preparation for a career in science.

Not too many years ago, a thoroughgoing training in both Latin and Greek constituted a valuable prerequisite for admission to training in many reputable schools of science. This was true not only in Europe, but also in the United States. It is still true in many of the great European countries, but, sad to relate, it is not generally so in present-day America. Today, the utilitarian spirit has seized control and obtained mastery of the minds of immature and misguided undergraduates, and prejudiced and uninformed teachers and professors. The net result is that the elective system rides the white steed of control, and the student is permitted to select those subjects which he considers will be useful and money-producing shortly after his graduation. The utilitarians say that Latin and Greek are "dead" languages. If this claim be allowed, let them be counselled,—*de mortuis nil nisi bonum.*

It is singularly significant that the more mature group of scientists here in America, many of whom, by the way, are well groomed in the classics, are the men who have contributed most to science and gained the highest prominence. These men constantly make acknowledgment of their indebtedness to classical studies in the fostering of their successful careers in science. They realize that intense preparation in these studies has given them a finer appreciation of the primary meaning of words, and has, therefore, made it really possible for them to understand how to use English, even to the extent of forming new words for new purposes. They are conscious of the fact that more than one-half our English vocabulary is founded on Latin, and that the terminology of science is made up almost wholly of Latin and Greek derivatives. If there are men of science, and fortunately they are not in the majority, who persist in saying that the ends of utility are not served even when a student succeeds through the study of Latin and Greek in mastering the vernacular and the very language of science itself, then of them it may be truly said, *damnant quod non intelligunt.*

It is regrettable that so many modern students of engineering have had absolutely no training in either Latin or Greek prior to admission to college. Since most engineering schools do not require these subjects, and since, furthermore, so much of the vital literature of science is written in German and French, it is not surprising that young men, contemplating a career in engineering, are urged by their high-school instructors to study the modern languages only. This is, however, a fundamental error in American education, particularly as it relates to the training of young engineers, because anyone who has studied the languages of the ancients, prior to taking courses in modern languages, realizes that there is something fundamentally deficient in the groundwork of the modern languages. The structure of the classical languages so completely dominates that of the modern languages as to render comparison foolish. What is even more important to us Americans is the fact that an absence of knowledge of the Latin grammar in particular, makes a proper understanding of English almost impossible. For it is undeniably certain that there are features of our language, distinctions of meaning, which cannot be brought out in the study of English unless one goes back to its mother tongue.

Only recently the writer had occasion to read in a New York newspaper a criticism by a distinguished personage that the methods of teaching modern languages in our schools were basically unsound, because they failed to produce students capable of conversing in these languages. This, of course, is true; but the same indictment could have been made against the methods employed in teaching the classics. In the case of the classical languages, however, it can honestly be

said that it is not the purpose to speak them (aren't they dead, anyway?); the purpose is fully to understand their structure, and in this way master our own English language to the extent that we can really speak it, not in dialect form, but in all its richness and purity. Perhaps, with this sort of foundation many students would find conversational mastery of French, German, and Spanish less difficult.

Considering the position of great trust that an engineer holds in his community and his responsibility of profound service in the welfare of his fellow men, it is clear that he should be a gentleman of the broadest culture. That he should have a fine technical background goes without saying, but that he should also be a master of the spoken and written word cannot be denied, if one considers his multiple relationships with employers and clients. Unfortunately, the main criticism of technological graduates today, if we accept the information they in part supply themselves, is that the limited cultural training given in schools of technology acts as a restrictive barrier to their ever feeling perfectly confident of speaking and writing with great facility, even in a technical vein.

This is not intended as a criticism of technical schools, here or elsewhere. As a matter of fact, we in America can boast of having the finest engineering schools in the world; but the prescribed courses of study are so intense as to leave insufficient time for cultural studies. The answer seems to lie in a six-year course, instead of the present four-year course, with the initial two years given over to the studies in English, the languages, mathematics, history, etc. Some of the larger engineering schools are, in fact, giving the six-year plan serious consideration at this very time.

It may be pointed out that even under the six-year plan the study of Latin and Greek would still be infeasible, since the study of German and French, especially German, would require so much time. This argument is not without water, but the difficulty can be met if the technical schools will demand, as a prerequisite for admission, four years of training in Latin and two years in Greek. In this way it would not be necessary to devote any time in the college work to a study of the classics.

Nor does it seem necessary that all the Latin shall be given in the high school, for the writer firmly believes that most children commence the study of the languages far too late in their curriculum. The study of Latin, and either French or German, could be started in the seventh grade of our elementary schools. The results, in all likelihood, would prove most gratifying. This is nothing new, for the plan known as the "Preparatory School Plan" was employed in Massachusetts for years. It may still be in vogue, but the writer is not certain. In the Belmont Street School of Worcester, Massachusetts, to cite a specific example, boys and girls averaging 75 or better for the sixth grade, could, if they so desired, enter the "Prep", where Latin and either German or French could be studied during the seventh and eighth grades. The "Prep" dismissed its students for the day at one o'clock so that they might have sufficient time for study, recreation, and preparation of the daily assignments. These students, if successful, finished the high school course in three and one-half years.

The psychological advantage of an early start in the study of the languages is apparent. So much of the earlier part of a language is learned by rote, the idiosyncracies of the preposition and conjunction, the intricate rules of punctuation, the varied rules of sentence structure, the identity of phrases and clauses, etc., that the simultaneous study of English and Latin would be certain to prove of tremendous value in proceeding to a complete conquest of the former at least. What with young minds clear and active and the memory faculty in the youthfulness of its full vigor, it is no wonder that the children of England and Germany—many of whom begin the study of Latin between the ages of 8 and 12, and Greek between 14 and 16—evidence a greater capacity in language study than our American boys and girls. The capacity is not necessarily inherent. It is a capacity and advantage accruing from longer hours and years of study. American boys and girls have the ability. Give them the time and the opportunity, and watch the results. Then perhaps they could converse in a way which would satisfy even the sharpest critics of language teaching methods in our schools.

Although we are restricted here to a consideration of classical training for scientists, it should be evident that the requirements suggested for potential engineers should be supplemented by additional years of study, particularly in the college course, for all prospective teachers of science, and young men who seek careers in theology, law, medicine, and practical affairs. The thesis for a rigorous course in the classics for all men contemplating a career in the professions was well established by the late Professor Francis W. Kelsey, distinguished American classical scholar, who quoted the late Senator George Frisbie Hoar, of Massachusetts, outstanding scholar and statesman, as having said in speaking of the highest types of character and personality:

> "I have a very deep-seated and strong conviction that one powerful influence in forming such character, in the matter of taste, of mental vigor, of the capacity for public speaking and for writing, in the power of conveying with clearness and force and persuasive power, without loss in the transmission, the thought that is in the speaker or writer to the mind of the people, is to study and translate what are called the classics, the great Latin and Greek authors. I think this is not only an important but an essential instrumentality . . . Of one thing I feel very confident. That is that the men whom I have known at the bar, in public life, and in the pulpit, who have been good Latin or Greek scholars, and who have kept up the love and study of either language through life, especially those who have been lovers of Greek, have shown great superiority in the matter of effective public speaking."

An endless list of scientific celebrities could be cited as real advocates of a sound training in the classics as a proper approach to a career in science. It will suf-

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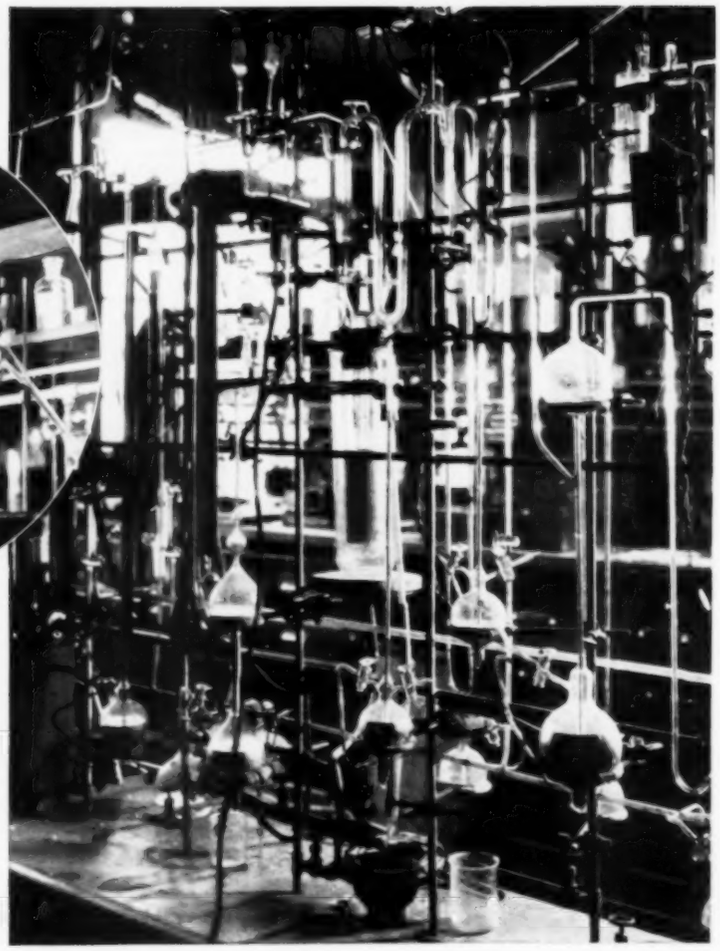

THE SIMPLEST HIGH SCHOOL EXPERIMENT

THE MOST COMPLEX CHEMICAL RESEARCH

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BALANCED GLASS

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FATHER TIME

Continued from Page Sixty-seven

was surely at least six hundredths of a second, even though the mean of eight stars was taken! It is the firm conviction of the writer that the demands for extremely accurate time are now getting so insistent that as much care should be taken in choosing the site for a Time Service as for any other astronomical observatory. We would rejoice to see a time service with the very best of modern facilities, placed side by side with the new 200-inch telescope on Mount Palomar in California, whose site was so carefully chosen for "optimum seeing." Since the precise positions of the "ten day" and other stars used by time services are ultimately dependent on meridian circle observations, subject to most of the errors already enumerated, such meridian circle measurements should also be taken with the most modern facilities at a site of "optimum seeing" like Mount Palomar.

KEEPING ACCURATE TIME

We now turn to the second task of "Father Time!" He must not only wrest the most accurate time possible from his primary stellar clocks, but he must also preserve it just as faithfully, in order later to communicate it to others. Here we meet with a new swarm of troubles. At our Observatory we must fight the following enemies: *(a)* temperature changes; *(b)* pressure changes; *(c)* tilting of the pier to which the clock is attached, due to variable insulation on the astronomical building, and also to changes of ground water; *(d)* earthquakes; *(e)* maintenance difficulties of various kinds.

The length of the pendulum, at least of the master clock, varies with temperature, thus changing the clock rate. Of course, one could try to get the rate of change per degree, but this is unsatisfactory. By far the best method is to eliminate temperature changes altogether. This is done by placing the master clocks in a specially insulated chamber, whose temperature is kept very constant by means of a thermostat, which automatically puts on carbon lamps to heat the vault whenever the temperature gets even a fraction of a degree below a certain norm, chosen a little above the maximum temperature to be expected in the vault during the year. A fan periodically stirs the air to avoid layers of air of different temperatures.

Pressure changes also vary the clock rate, mainly by changing the density of the surrounding air in which the pendulum swings, and its frictional resistance to the swing. This again could be allowed for, after a fashion, but it is best avoided altogether by enclosing the master clock in a hermetically sealed metal and glass case, thus keeping the clock under a constant reduced pressure. This has the further advantage of excluding all possible effects due to changing humidity.

The next source of error may seem astounding to many, *i.e.*, the effect of the sun's heat on the sides of the astronomical building. This heating is more on one side than on another, thus excessively expanding one side, producing a tilt of the whole building. This must affect all the surrounding ground in some way, since, although the clock piers are entirely separated from the building walls, still the tilt definitely affects them. This has been proved in two ways: by the variable spacing between the lines of the record of our Wiechert seismograph nearby; and by experiments with a sensitive tiltmeter placed on one of the piers, which showed a definite diurnal tilt. How does this affect the clocks? On very hot days the tilt changes the relation between the pendulum and its suspension introducing a periodic change in rate of at least as much as one or two hundredths of a second daily.

Perhaps the best way of proving this change of clock rate is as follows: Some five times a day, on a chronograph accurate to at least one two-hundredths of a second, we record the seconds' beats of our master clocks. Without added corrections of any kind, we use these records to plot differences of time readings and of rates between the clocks. This is something relative, and does not depend at all on the absolute time. Such a record is a very useful check upon the clocks.

Suppose, in thus plotting relative differences between readings of master clocks A, B and C, we find the plot A-B gives a fine straight line for days, but that both plots B-C and A-C show a sudden change at the same time. Since our clocks swing in different planes, we can generally assume that the clock common to the two plots B-C and A-C, *i.e.*, clock C, has changed its rate, but that clocks A and B both have had a steady rate for the whole time their difference-plot has been straight. During our season of rather cool, clear weather, as in February, if we have no quakes and if there is not much rain to change the ground water level, our clocks may show almost perfectly straight lines for their relative rates for weeks on end. In fact, this year two of our clocks showed a fine straight line for relative rate for about a month. A portion of such line is shown in Figure A.

Now we can understand how our plots help to show tilting. Since the clocks all swing in different planes, the effect of tilting on their respective rates is naturally different for each, and hence the daily tilting period will show in the plot of the difference of their rates. The diagram appended (Fig. B) indicates this nicely.

Besides the heating effect on the building, we have another peculiar trouble. During heavy rains there are frequent changes of level in the ground water; and as the sea level is just a few feet below the Observatory floor, changes in this level may tilt the cement piers, large as they are, and this in turn may change the clock rates by more than one or two hundredths of a second (Fig. C). In building a new Observatory for a time service, these two sources of error should be carefully guarded against.

But the most uncertain and serious trouble for us, is the earthquake. We do not often experience such large quakes as that of 1937, when the spring suspension of one of our master clocks was twisted through ninety degrees. But even shocks that can just about be felt will often alter the delicate clock equilibrium, thus changing the clock rate temporarily by straining the

delicate spring suspension, or perhaps even permanently by giving things a new "set." The faithful plotting, five or six times a day, of the relative rates of our master clocks by the method already described tells us at once which clocks have probably been the most affected by the shock, so that we can discard their readings for the time being as unreliable. The diagram appended (Fig. D), shows the pronounced effect on the relative clock rates by even a very moderate quake.

Is there any remedy for such earthquake troubles? We are quite sceptical whether any master pendulum clock can be made so rugged as not to show some effects from such shocks. The solution appears to be rather in another direction, *i.e.*, in the possession of at least one auxiliary quartz crystal chronometer. It would be outside the scope of this paper to describe this new invention fully; but it consists essentially, not in a pendulum at all, but in a vibrating quartz crystal whose very high frequency vibrations are carried down step by step by means of peculiar types of radio tubes, until a frequency is obtained small enough to run a synchronous motor and dial. Such a chronometer, if properly suspended, should be able to go through all but very severe quakes with hardly any effect on its rate. This clock is the newest advance. Already it would seem that its accuracy exceeds that of the very best pendulum clocks. Its future seems bright indeed.

Just a few words more about other clock difficulties which, though minor, can be quite irritating. At first, all three of our master clocks were placed on one very large pier; but it was found that the pendulum swing of each of the clocks set up synchronous vibrations in the pier, large as it was, which vibrations were communicated to the other clocks, with mutual interference of rates. So, like bad children, the three master clocks had to be separated and put on individual piers, well isolated from each other. Then there are the usual difficulties of keeping in proper shape the electric batteries that serve to give the impulses to the pendulums. Care must be taken in avoiding sparking contacts which become dirty and thus necessitate opening up the clock case for cleaning. There may be slight leaks in the sealing of the clock case, thus changing clock rates, etc., etc. All in all, we are often tempted to complain that our master clocks demand as much attention as babies!

DISPENSING TIME

This is the third and last step, and here, too, we must guard against a different set of errors if we would attain to one-hundredth's of a second accuracy. The various steps in time distribution are: *(a)* sending the time signals, usually by wire, to the wireless transmitting stations; *(b)* travel of the waves through space to the receiver; *(c)* reception and recording of the signals.

The master clocks themselves are not used to transmit the signals, since they are only rarely touched when absolutely necessary for repairs. To correct them several times a day would absolutely destroy their accuracy; hence, they are allowed to accumulate their errors. But another reliable clock is set to the exact hundredths of a second correct time by chronograph comparison with the masters. This must be done quite close to the transmission time, otherwise the emitting mechanism itself may in the meantime get "out of tune."

At the proper time the transmitting clock at the Observatory sends the signal impulse, usually by wire, to the wireless station, where, by means of relays, the signal is sent out from the wireless antennae. Now these relays, especially if mechanical, may have very appreciable lags in operation. These lags must be allowed for if the wireless signal is to leave the antennae precisely on time. The emitting station is usually so close to the Time Observatory that no allowance need be made for the time it takes the electric current to pass between them, but if the lag due to the relays is, let us say, 0.04 second, then the emitting mechanism at the Observatory must be set 0.04 second *ahead* of the correct time to allow for this lag. Unfortunately such lags may not be constant unless great care is used. It would be better if all relays in the line were very fast working vacuum-tube relays, to avoid such inconstancy.

Now that the signal is on the air, what is the next source of error? Surprising to relate, it is the apparently different times it often takes for the radio wave to go from the transmitter to the receiving station. But surely this is negligible, since the speed of radio waves is almost incredibly large, like that of light! Light, indeed, travels so fast that it could encircle the earth seven times in one second. But remember that the transmitting and receiving stations may be very far apart, one-third or even one-half of the earth's circumference apart. Hence, when I receive the time signals from Washington (NAA) at Manila, the lag of the signal in the air is about 0.05 second, and must surely be allowed for. But is this not accurately constant, and hence really no source of error and worry? Are we so sure of this? In fact, we are very much concerned about it at present.

When time signals are used to get differences of longitude between distant places, it is found that the longitude values vary more than the known sources of error warrant. Can we, therefore, immediately deduce that the Wegener hypothesis is correct, which says that longitude differences and hence distances between continents, are changing? By no means, for we must, before coming to a decision, take into account the peculiar properties of radio waves of high frequency (short waves). When the distance between stations is long, then the short waves do not follow the earth's surface accurately, describing the arc of a great circle, advancing always along an identical path. These short radio waves go to the upper air, are reflected back to earth from various heights (the so-called Heaviside layers) at various times of the day and year, and, finally, perhaps after bouncing back and forth between the Heaviside layers and the earth's surface several times, reach the receiving station. Consequently, we can see that the distance traveled by a short-wave time signal is

usually not the shortest possible one along the earth's surface, and the additional distance of path, besides being at times appreciable, may also be variable from day to night, from season to season, and even from one high frequency to another. It has even been discovered, by means of directional antennae, that often the short waves do not reach the receiver from the direction they should if they followed a direct route, but from an unexpected azimuth! In fact, if we assumed that the short wave radio wave traveled the shortest path, then the calculated velocity for long distances would be quite appreciably less than that of light. This would certainly indicate that the lag over long distances is due to erratic path. Until this lag becomes accurately known, we may find trouble in proving Wegener's hypothesis by means of time signals—we may be baffled in our attempts for one-hundredths of a second accuracy in time transmission.

But can we not use long waves, which do not skip and bounce like the short waves, but travel straight forward to their goal? Unfortunately, the expense for a powerful long-wave station is enormous compared with a shortwave station equally efficient for ordinary commercial purposes. Furthermore, especially during the day, the static on long wave is so strong that it usually prevents satisfactory automatic reception of the time signal. It is difficult to see yet just how to allow accurately for the vagaries of short-wave paths, and it is extremely doubtful if the new Armstrong method of frequency modulation can be used on long waves to get rid of the static there.

One source of error still remains to be mentioned, the lag of the signal in going through the radio receiver itself, and then on to the chronograph for comparison with the master clocks of the receiving Observatory. Here, again, vacuum-tube relays between radio set and chronograph, etc., are advisable instead of mechanical relays with possible variable lag. As to the lag in going through the receiver itself, this may be slightly variable for loud and faint signals, and perhaps also for frequency of radio wave. This, however, can usually be quite accurately calculated experimentally, by sending an artificial signal two ways, one way direct to the chronograph, the other at the same time but first through the radio receiver. The difference in time taken for the signal to travel the two different paths will give the lag of the receiver.

We have now finished the story of our troubles except for several recondite difficulties too technical to mention here. I am sure that by now you will all agree that "Father Time", in his quest for meticulous accuracy, has certainly no sinecure! ●

For Your Information . . .

The author of the series of general science textbooks mentioned in the advertisement of the John C. Winston Company on page 86 is the Franklin B. Carroll who wrote the shrewd article on *Choosing a General Science Textbook* in our June, 1939, number. Teachers will find it profitable to read the article again before making a final selection of new textbooks in the field.

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Deep Focus Earthquakes

Continued from Page Seventy-two

2. The disturbance lasted very much longer as a second shock occurred before the effects of the first had died away.

Although the fact of the occurrence of these earthquakes has been established, the mechanism by which they occur is still obscure. Normal earthquakes result from a sudden release of strain energy in the crust of the earth. Slow crustal motions are going on continuously in the processes of mountain building, valley forming and ocean deepening and shallowing. These displacements cause the stretching of some parts of the surface layer and the compressing of others until the strains become so great that rupture occurs over a wide area. The potential energy of the strained layers is suddenly released and violent motions are set up in the surroundings—the seismologists then say "a quake is on."

The seismograms of deep focus earthquakes lead us to believe that there is no fundamental difference between the shallow shocks and the deep quakes; such differences as do exist can be accounted for in terms of the change in depth and not in terms of a change in mechanism. The prominence of the transverse waves on the deep focus seismograms indicates that a great amount of shear energy must have been set free. This is the form of energy stored up during a change of shape, or a distortion. To produce these distortions, forces must be exerted so as to produce something similar to a twist in the material. Geologists believe, however, that the regions below the surface layers are in equilibrium, the pressure increasing with depth much as it does in a body of water at rest in a tank; the level at which hydrostatic equilibrium sets in is about 125 kms. below the surface of the earth. The question that confronts seismologists and geologists may be stated thus: How can inequalities in pressure be set up in an homogeneous mass in equilibrium until great quantities of energy are stored up, which are then released with explosive violence, as they are in deep focus earthquakes?

A further difficulty presents itself if we take into account the increase in temperature with depth as we penetrate into the earth. At a depth of only about 75 kms., the temperature must exceed 1000° C., which surpasses the melting point of common rocks. The material at this depth must be fluid, so that any unbalanced tension causes flow rather than distortion as in a solid. The seismologist maintains however that the rigidity of the earth increases with depth for great distances so that we are faced with the dilemma of requiring a substance to store up great energy of distortion when its rigidity is large and its strength is small, and when acted on by unbalanced tensions that approach zero in magnitude. ●

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HOW FERNS GROW

Continued from Page Seventy-eight

At the posterior portion are produced two outgrowths, the rhizoids and the antherids. The rhizoids are outgrowths of cells and are for the purpose of anchoring the gametophyte and supplying it with water and nutrient salts. They are produced only at the posterior end.

The antherids are produced generally among the rhizoids and are also outgrowths of cells (Fig. 16). They are small, sac-like, nearly spherical in structure, composed of three outer wall cells, and when mature, a number of inner spirally coiled cells, the sperms or antherozoids, which are provided with numerous hair-like cilia by means of which their swimming motions are made possible. Sometimes a single antherid may produce 128 antherozoids (Fig. 17). Since on the lower surface of a single prothallium more than 100 antherids are sometimes produced, a gametophyte may form as many as 12,800 antherozoids. When they are ready to be discharged, the outer, or cover cell of the antherid separates from it and the antherozoids can be observed to escape through the opening and after a short interval their swimming motions can be followed.

At the anterior end of the gametophyte and on the thickened portion already described as the cushion, the archegones are formed. The outer portion of the archegone is finger-like and is known as the neck. It is joined to the enlarged part wholly embedded in the cushion. It is this enlarged portion of the archegone, or venter, that contains the egg (Fig. 18). In the neck, there is a canal which is filled with a slime containing a small amount of malic acid. When the archegone is ripe, the outer cells of the neck separate and through the opening produced the slime is discharged. The antherozoids are attracted to it by the acid and many enter the neck, but only one enters the egg (Fig. 19). This union of egg and sperm, known as fertilization, is an important event in the life cycle of the fern. The resulting cell or zygote is the beginning of the asexual generation or sporophyte. The egg divides twice and an embryo in the form of a quadrant is produced (Fig. 20). Each cell of this embryo is destined to produce a certain portion of the plant. One cell forms the root, another the leaf, another the foot, and the fourth one produces the stem or rhizome of the brake (Fig. 21). The leaf and the root perform the nutritive functions of the plant. The foot is embedded in the gametophyte and is the means by which the young plant obtains a considerable amount of food.

The relationship of gametophyte and sporophyte in the life cycle is evident. When the embryo is embedded in the venter of the archegone, it is wholly parasitic. Later when the first leaf and the first root are produced, it is partially independent, and, finally, after the rhizome has been formed, the roots and leaves appear and the sporophyte becomes independent.

It may be interesting to refer to the time required for a fern to develop to maturity. The mature gametophyte may be produced from a spore in about a month. Then fertilization may occur and in a few weeks the young sporophyte with root, leaf, and foot has made its appearance. The first leaf is simple and rarely reaches a height of more than three quarters of an inch. In the course of a few weeks other larger and more finely divided leaves will appear. There may be as many as ten or twelve such leaves formed, each one after the first being larger and more complex than the preceding one. In the meantime, a period of six months to a year has elapsed and the gametophyte may be of a pale green color or it may have almost disappeared. Much of the food for the growing sporophyte has in the meantime been supplied by the prothallium, and hence, it has been exhausted. At the end of about a year the stem, which has been belated in its development, has grown to a considerable length and from it are produced the first ordinary foliage leaves and the roots. Within the next year or so, the fronds may be formed. In nature, probably three years elapse ordinarily between the germination of the spore and the formation of the mature plant with fronds.

THE ALTERNATION OF GENERATIONS IN THE FERN

When the spore of the fern is produced in the spore sac, the gametophyte or the sexual generation begins its existence. The spore is destined to produce the heart-shaped prothallium which forms the gametes—eggs and sperms. As a result of fertilization the zygote, then the embryo, and finally the sporophyte with rhizome, leaf, frond, and root are produced. The sporophyte again forms the spores. It is evident that the haploid and sexual or gamete-bearing generation alternates with the diploid and asexual generation, or spore-bearing generation. This alternation of generations, characteristic of our ferns and of a number of other groups of plants, was discovered about three quarters of a century ago and is one of the most interesting phenomena in plants.

SOME WAYS IN WHICH FERNS REPRODUCE

When the heart-shaped prothallium is grown in subdued light, it will produce filaments which resemble those formed by germinating spores. When the culture with these prothallia is placed under favorable light conditions, the filaments will form heart-shaped gametophytes (Fig. 22). In time these will separate from the parent prothallium, and become independent. When pieces of a gametophyte are removed and planted, many secondary gametophytes will also be produced.

The ordinary fern plant, or the sporophyte, has a number of methods of reproduction. The brake, however, can reproduce itself in only one way. As a result of injury to a portion of a rhizome between its ends the tissue may die, and, finally, as disintegration takes place new plants are formed in consequence of separation of the rhizome into distinct parts. As the stem branches (Fig. 23) and the older part of the axis dies, a number of new plants may also be produced.

Some ferns, like one of the Boston ferns, form runners above the soil. These may develop new plants as shown in figure 24. Some ferns, like the ostrich fern, produce runners below the surface of the soil. A few of our ferns form tubers (Fig. 25) such as is the case in some of the Boston ferns. These tubers are similar to common potato tubers and reproduce new plants. In

one of the common bladder ferns many small bulblets resembling those of the common tiger lily are produced on the leaves (Fig. 26). When these bulblets are shed in the autumn, each germinates to form a small plant. In a few ferns small plants are formed on the surface of the leaf. Finally, they exhaust the food in the leaf which gradually breaks down and comes to lie on the surface of the soil. Many independent plants then become established. The common walking fern is a most interesting one so far as reproduction is concerned. When the tip of its leaf comes into contact with the soil, a new plant is produced (Fig. 27). Frequently the new plant, thus formed will repeat the process before the connection between it and the parent plant is lost.

There are still other ways in which ferns reproduce, but it is not within the scope of this paper to discuss these methods of reproduction. ●

THE EXPERIMENT

Continued from Page Sixty-three

The ordinary high school or college student is not in a position to conduct experiments of this type. But he can experience the thrill, vicariously, by learning of the experiments that lead to new knowledge. The historical approach, aided by occasional demonstration, is not only inspirational, but also provides that perspective which is so important if true values are to be recognized. When this approach is used, the student is introduced to authority, learns the value of profiting from the experience of others, and gains an appreciation of the scientific method viewed in its truest light.

When a student finds it difficult to understand or appreciate information provided through historical study, he should be given the opportunity, in a weekly experimental period, to experiment for himself. Experiments should be optional, and not obligatory. In order to ensure complete participation it might be feasible for the instructor to prepare a list of experiments based on the work of the week and have the students make a choice. Where the individual finds it desirable to go ahead along advanced lines, he should not be discouraged. The teacher has already demonstrated such phases of the work as he has considered necessary to the development of the topic under discussion. Much of the experimentation may be along corollary lines.

The formal experiment, in this way, loses much of its formality, but the values of proper procedure are not lost as the student checks his results with the results of others, discovers and corrects sources of error. Such work is inspirational and constructive in its implications.

When the backgrounds and education of the great scientists are studied, students are given a clear picture of the path science must cover in its voyage of discovery. They learn how each individual's efforts are based, to a large extent, on a foundation of knowledge provided by others. They also learn to appreciate the mutability of facts.

With procedures as they are, with long syllabuses, students often gain the concept that it is their function to acquire and store as many facts as possible. The situation is becoming as absurd as it would be to expect a lawyer to know all the laws, or a doctor to be familiar with all phases of all diseases. The lawyer, and the doctor to almost as great an extent, could not possibly hope to learn, and much less remember, every fact included in his field. But he is expected to be familiar with procedures and sources of knowledge. So, the science student should learn how to acquire knowledge and not amass it.

Students should be provided with a broad base of information on which to build such special knowledge as each finds necessary and desirable in his cultural and professional life. They should be taught to conceive education as a process of growth toward an awareness of a dynamic world. The facts of today are not the facts of tomorrow. Yesterday, flight by a heavier than air machine was impossible. Yesterday, the cause of measles was considered to be a filterable virus. Today's facts may be tomorrow's fallacies. But life must be lived today. Work must be based on what we know now. So we must learn to be ever ready to relearn.

We cannot check and investigate every bit of information we live by. We must depend on what the experience of others has taught us. We should choose our preceptors carefully and go forward where progress seems indicated. Facts are tools, tools that may be improved. They should be used until better ones are available.

Let us teach our students how to apply their knowledge, how to live and work with others. Let us teach them to be aware of progress and, above all, to be awake to the future. ●

To Help You Teach

Continued from Page Sixty-two

where to select some of the more successful science project material they have used or developed and submit it for display at the next Science Conference.

The projects submitted need not be original; neither need they necessarily be elaborate or expensive. They may be in the form of home-made apparatus, collected materials, herbaria, specimens, displays, teaching devices, models, carvings, drawings, photographic work, special charts, etc. They may be connected with any high school science.

You may send in a display even if you are unable to be in attendance. This is an opportunity for *you* to help other teachers of science.

Each display should be labeled with the full name and address of the school, the name of the teacher, and the name of the student. They should be addressed to the Director of the Science Conference, Duquesne University, Pittsburgh, Pa., and shipped so that they will arrive on or before February 12, 1940.

All project material will be returned, carriage paid, to the cooperating schools after the Conference. ●

Cosmic Rays (1900-1938)

Continued from Page Sixty-nine

for by the radius of the electrical ring of current and by the amount of current flowing in it.

Cosmic rays do not bombard the earth with equal intensity from all directions, but their strength increases with the distance north and south of the earth's equator. This theory is held both by Dr. Compton and by Dr. T. H. Johnson of Franklin Institute.[10]

Three major methods of observing cosmic rays have been developed. By means of an ionization chamber filled with gas such as argon, under high pressure, the cosmic rays can be measured in terms of the conductivity or ionization they produce in the gas. The cloud expansion chamber invented by C. T. R. Wilson, makes visible the paths of ionizing particles associated with the cosmic rays as they break into ions some of the air molecules through which they pass. Highly sensitive ion chambers, connected through amplifying tubes to electrical recorders serve to count the cosmic rays as they pass through the chambers. These are known as "counting tubes." By arranging these tubes in pairs, so connected that they will record only when both are excited simultaneously, it is possible to study the direction from which the cosmic rays are coming. A new device has recently been developed by Drs. E. D. Stevenson and Ivan A. Getting which is technically known as a scaling circuit. Random electrical impulses coming only one fifty-thousandth of a second apart can be distinguished and counted. The circuit is so stable that counts can be made at these terrific speeds for months on end without any effective changes in the equipment.

When the cosmic ray was discovered in 1900, it opened a vast new realm of physics. During the last thirty-eight years, great progress has been made in this new field, but there is still much to be accomplished before the physicist can truthfully say that he knows exactly what the cosmic ray particles are, where they come from, or how or when they were formed. ●

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[16]*Science Supplement*, July 15, 1932, p. 6, "Cosmic Rays."

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SCIENCE LESSONS

Continued from Page Seventy-four

greed dominate the economic world, there will be cold indifference to the welfare of the average man. Where favoritism and graft permeate the political world, good government is secondary to party politics and financial interests. Without God, man-made theorists of philosophy and morality will utterly disregard the welfare of the individual and the common good of the country. Profits, then, not ideals, will dominate and be the motivating force.

Science cannot solve such problems. But from the study of botany we can learn a wondrous lesson.

What happens to the vine that, breaking forth into bud, joyous and green, exquisite of form, makes the land lovely in the springtime? The husbandman comes early, with the pruning hook and shears, and strips it bare of its wandering garlands, cutting deep and sure. But under the despoiling hands, in its loss and pain, it yields itself more perfect. The bleeding limbs are hardened into wood; the thinned out bunches ripen into fruit, more full and precious to the purple prime. Then comes the vintage. Does the vine, bending low beneath the weight of its wealth, rejoice? See, hands are ready to tear down the treasures of the grape; feet are there to tread them in the wine press.

The vine stands stripped and desolate. Having given all, it has its own dark time. There seems to be no return for the comfort and glory of its own gift to man. Only pain and loss are its share. After the sap has ceased to flow, the vine is cut back to the very stem: despoiled, disfigured, left a leafless stock, alone through the dark days to come. And all through the winter time the wine gives joy to those who otherwise would be dismal in the cold.

But where is the vine? Out amid the frost it stands, with only this grace left, that it endures through the long winter, and next year blooms again, not bitter for the torment undergone; not barren for the fullness yielded up; but as fair and fruitful towards the sacrifice as if no touch had come to it but the soft airs of heaven and the dews of earth. Is not this a lesson for life?

"Measure thy life by loss, instead of gain;
Not by the wine drunk, but by the wine
poured forth;
For love's strength standeth in love's sacrifice;
And he who suffers most has most to give." ●

Questions . . .

Among the questions discussed at a recent Duquesne University Conference for teachers of science were the following:

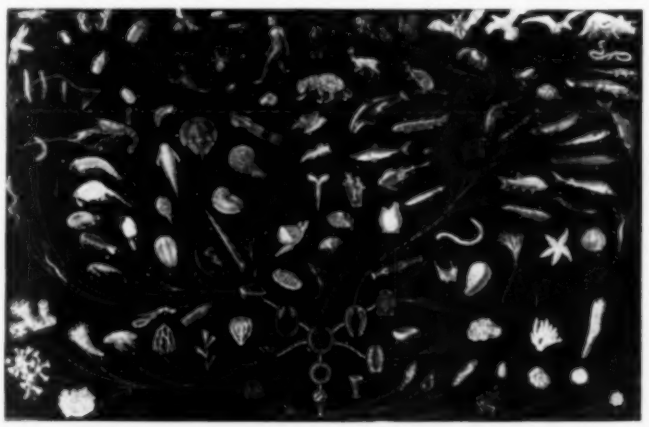
In high school science teaching shall we strive for thoroughness or extent of coverage?

1. If we favor thoroughness, what is the criterion for selection?

2. Do we want:

   Preparation for life or for college?
   Depth or scope of knowledge? Skyscrapers or one-room cottages?
   A harmonious development of the faculties, or merely factual knowledge?
   To inspire a desire for quest, or merely to "get the lesson?"
   To develop a dynamic force that will help solve daily problems, or to have finished "cold-storage products?"
   To sacrifice content in order to develop scientific attitudes?
   To acquaint pupils with a wide variety of significant scientific principles, or to intensify and make more permanent a few major factors?

3. Criticize Thorndike: "It is not scientific to spend two hours in manipulation . . . . which could be better learned by two minutes of thought. Washing bottles, connecting wires, putting away test tubes are not magic sources of intellectual growth."



Illustrated above: ***Chart FC 1 Relationships of the Animal Kingdom.*** In full color, 115 pictures serve to convey the most accurate conception of classification and organization of animals. Embryology provides the basis for the arrangement. This classroom necessity is of large size, 45 x 68 inches, is priced at **$11.00.** *We will gladly send this superb chart subject to your approval.*

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A Conductivity Kit

Continued from Page Seventy-nine

then repeated using sugar instead of salt. Other tests include the conductivity of several common acids, several bases, several salts, tap water, sea water, alcohol, glycerin, kerosene, etc. The result of each test is tabulated as soon as completed, conductivity being indicated by plus, and non-conductivity by minus signs. A dissociation equation is then written for each case of conductivity.

NEUTRALIZATION

A most interesting experiment may be performed to show the ionic nature of neutralization. The kit is used in the manner shown in Figure 4. Note that the electrodes in this case are ordinary leads from a mechanical pencil. With a little care and practice any student can add just the right amount of sulfuric acid so that the light will gradually get dimmer and dimmer until it goes out entirely. The pink color at this point is, of course, replaced by the milky white precipitate of barium sulfate. A few more drops of acid will relight the lamp.

Because all other salts produced by ordinary acids and bases are soluble and dissociate readily, this experiment cannot be done with reagents other than barium hydroxide and sulphuric acid. However, we sometimes have students repeat the experiment using sodium hydroxide in place of the barium hydroxide. Then we let them explain why the result is different. Most students readily see the reason.

STRONG AND WEAK ELECTROLYTES

ACIDS. Distilled water (about 25 cc) is placed in an evaporating dish and tested for conductivity. Then, with the electrodes remaining in the distilled water, one drop of concentrated sulfuric acid is added to the water and stirred. The light, of course, burns very brightly as soon as the acid mixes with the water. The experiment is then repeated using glacial acetic acid. As many as fifty drops of acetic acid may be needed in order to make the light as bright as that produced by the one drop of sulfuric acid.

SALTS. The conductivity of ammonium hydroxide and acetic acid is tested in separate evaporating dishes. Then, with the electrodes remaining in one of the solutions, the two solutions are mixed, to show that a strong salt may be made from a weak acid and a weak base.

ELECTROLYSIS

The decomposition of water by electrolysis may readily be shown by means of the kit when arranged as in Figure 5. A few drops of sulfuric acid must be added to the water. The electrodes in this case are small pieces of platinum foil. The tubes are ordinary 15 cm. test tubes which may be supported by means of burette clamps. Or the test tubes may be replaced by burettes. The wires leading to the platinum electrodes must be protected by very small-bore rubber tubing. ●

ALKACID (Alkaline or Acid and How Much) TEST PAPER

Fisher Alkacid Test Paper is used to determine the approximate pH of solutions over a range of pH 2 to pH 10 with an accuracy of ± 1 pH. It provides the means of determining not only whether a solution is acid or alkaline (as litmus paper does) but also indicates by distinct color changes how acid or alkaline the solution is.

Alkacid paper strips are 1/4" x 1 7/8" and orange in color. When they are immersed in a solution, the paper changes color as follows: pH 2, very acidic, red; pH 4, orange; pH 6, yellow; pH 8, green, and pH 10, strongly alkaline, blue. A chart on the label attached to each vial facilitates the comparison of a test strip with the five standard colors.

Per vial of 100 strips, $ .30; Per dozen vials, $3.00.

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The Fisher Thermostatically-Controlled Hot Plate is suitable for many routine heating operations in the laboratory. It is a quick-heating device with a thermostat to control the temperature at any point from 40° to 200°C. The heating surface is 4 inches in diameter. A convenient clamp on the side can be attached to a support stand. Wattage, 750 (used intermittently), for 110 volts, A.C. only, complete with cord and plug. Each, $5.00

FISHER TEST TUBE MARKERS

These Markers consist of a frosted celluloid blank with a supporting back and frame of tinned spring steel. They fit test tubes of 5/8" to 3/4" outside diameter. The frosted surface will take pencil markings and is readily cleaned. The Markers are slipped on and off the tubes easily and can be used repeatedly. Much more convenient than labels.

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On Classical Training For a Career in Science

Continued from Page Eighty-one

fice, however, to quote two of the world's leading scientists. Albert Einstein, the most outstanding theoretical physicist in the world today, says of Latin, "This subject is superior to any modern language for developing the power of thinking." Robert Andrews Millikan, of the California Institute of Technology, perhaps the leading American scientist and a Nobel Prize winner in physics, in an address before the Phi Beta Kappa alumni in 1931, said in part:

> "How thoroughly I ought to recognize and actually do recognize the absolute necessity of the humanistic studies is revealed by the following facts better than by any protestations, either of affection or of dislike, that I might make. First, not only do I myself hold the Bachelor of Arts degree, and not only have my sons absorbed between them nine years of Latin, but I never entered upon nor even tasted scientific studies in any thoroughgoing way until after I graduated from college . . . The second basis that I have for laying claim to a breadth of interest in humanistic as well as in scientific studies is found in the fact that in the institution with which I am associated the so-called humanities are pursued with an intensity and a devotion such as characterizes, so far as I can discover, no other school that calls itself a school of technology, or that emphasizes in any way a professional objective."

The writer's colleagues in science can well appreciate the words of tribute of Senator Hoar, Professor Einstein, and Professor Millikan, although there are some, lacking the experience of training in Latin and Greek, who would regard their words as sentimental platitudes. These critics may be good scientists, but the ancient maxim, *Ne sutor ultra crepidam* still best describes the attitude of men who, profoundly trained in one field of thought, will take it upon themselves to speak with the voice of authority in any other.

The problem, then, of a proper training for a career in science presents itself for solution. We see the solution to be a handy and effective one. That this solution may be the more quickly applied, let those of us who love the classics and appreciate their great value rise up and start the war that will return them to their rightful place of supremacy.

There are yet modern Ciceros who dare cry out, *O tempora! O mores!* ●

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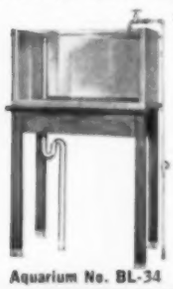

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